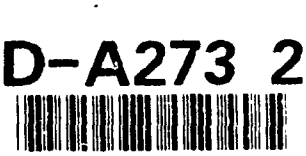

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Contractor Report ARCCD-CR-93005

DEVELOPMENT OF 30 MM THINWALL STEEL CARTRIDGE CASE

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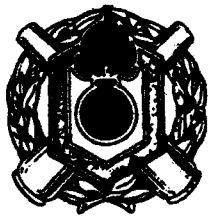
November 1993



U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

Close Combat Armaments Center

Picatinny Arsenal, New Jersey

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Amron Corporation was awarded a contract to develop a 30-mm thinwall steel cartridge case for use in the M230 chain gun which is the secondary armament system for the Apache helicopter. The contract was divided into two phases. Phase I entailed the manufacture and ballistic testing of 800 cases to prove design integrity. During Phase II, 10,255 cases were tested with no anomalies encountered. Based on achieved results, it was concluded that an adequate case design had been attained and a manufacturing specification to be used for future procurements should be written.

14. SUBJECT TERMS

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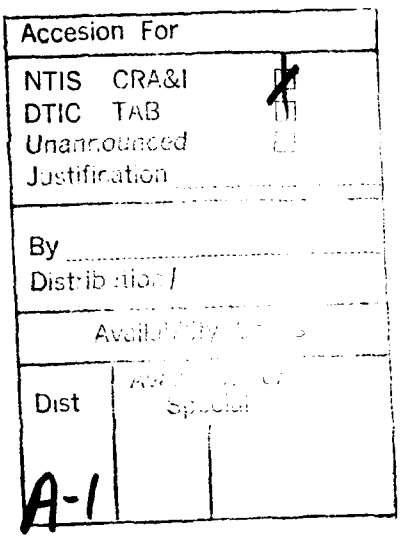
CONTENTS



TABLES

FIGURES

30mm THINWALL STEEL CARTRIDGE CASE FINAL REPORT

INTRODUCTION

On September 29, 1977, Contract DAAK10-77-C-0224 was awarded to the Amron Corporation, Waukesha, Wisconsin, to design and develop a 30mm light-weight steel cartridge case. The weight reduction was to be accomplished by reducing the sidewall thickness of the cartridge case and altering the internal base geometry. Outside envelope of the new case design was to correlate as closely as possible to the configuration of the 30mm aluminum light-weight cartridge case.

Once case design was finalized, the thinwall case was to function without casualty in the ADEN, DEFA and M230 gun systems.

At the conclusion of this contract, results achieved and a review of data accumulated was performed. It was decided that the case design did have merit, and further development should commence to correct minor discrepancies which were encountered.

On September 12, 1978, Contract DAAK10-78-C-0336 was issued to manufacture and test an additional 400 cartridge cases to correct these discrepancies. This contract was completed in December of 1979 with the conclusion that an adequate cartridge case design had been achieved.

On August 30, 1985, Contract DAAA21-85-C-0280 was awarded to the Amron Corporation to continue development on the thinwall steel cartridge case into the prequalification and qualification stages. The case which would be manufactured was to function reliably in both the M230 chain gun and ADEN weapon systems and meet the requirements of specification DOD-C-63976.

This report will address the work accomplishment achieved during the administration of this final contract.

I. CARTRIDGE CASE DESIGNS

A. Aluminum Case Design

The aluminum cartridge case shown in Figure 1 is the current case component for ammunition being used in the M230 chain gun and ADEN weapon systems.

The case weighs approximately 56 grams and has an internal volume of 67 cubic centimeters when measured to the mouth of the cartridge case.

The case is manufactured from 7475 aluminum; then heat-treated to a T-76 condition. The case is qualified for use in the M788 target practice and M789 high-explosive, dual-purpose, loaded rounds.

B. Purpose of Steel Case Design

The use of 30mm thinwall steel cartridge case type ammunition in a crew-served weapon application was one of the prime reasons for the development of the thinwall steel cartridge case.

In addition to this requirement, the thinwall steel case has several other distinct advantages. These are:

1. A greater internal volume over the current aluminum case. This attribute allows for an increased amount of propellant which can be loaded into the case.

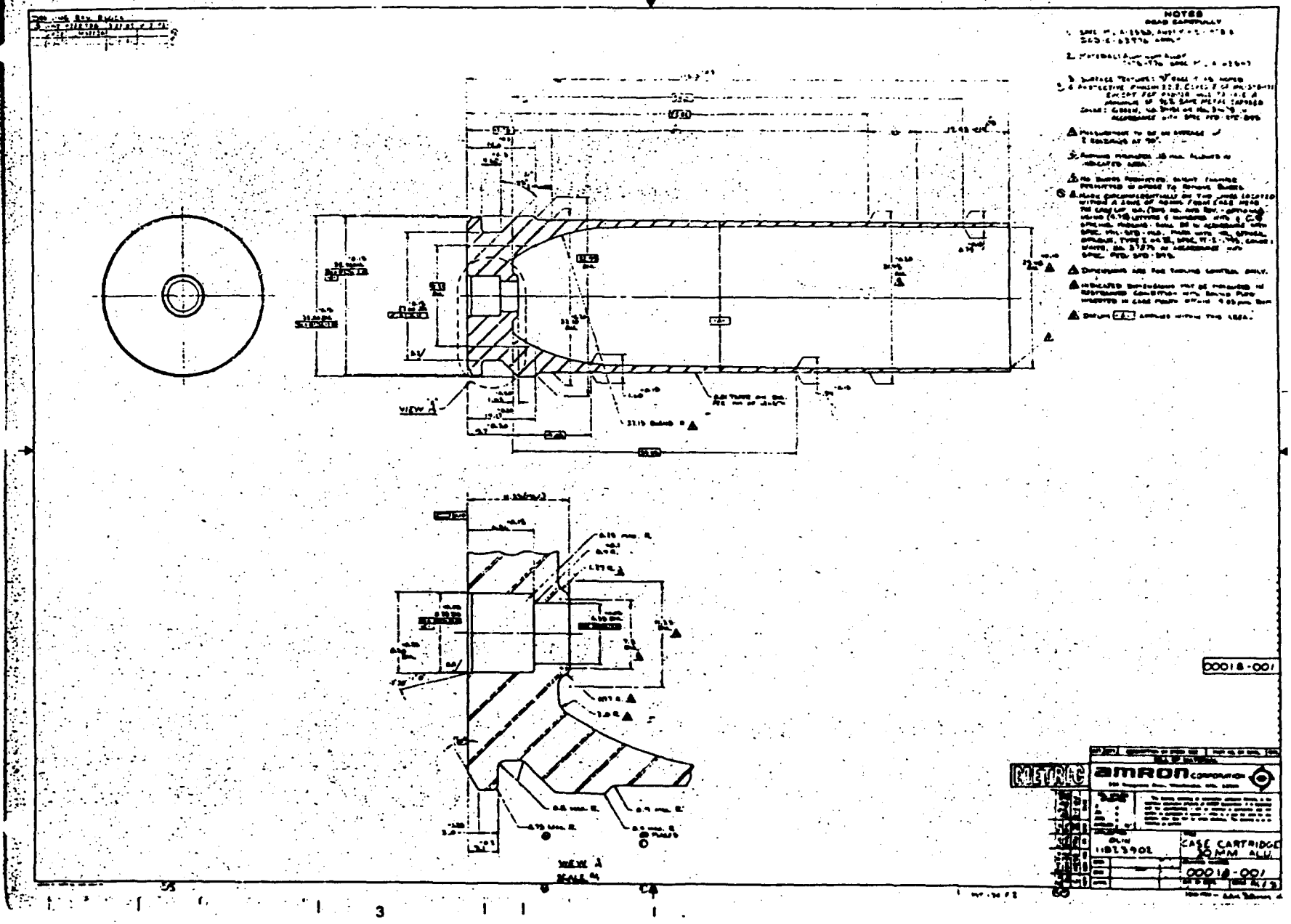
2. An increase in velocity is obtainable due to the additional internal volume.

3. Case can operate at higher internal pressure levels if required. This is facilitated by the difference in strength of the two materials, aluminum vs. steel.

   The only disadvantage of the steel cartridge case when compared to the aluminum case is the differential in total weight.

   Although the sidewalls and base of the steel cartridge case are minimized within structural limits, the steel case will always be heavier caused by the differential in the density of the two materials.

FIGURE 1 - 30mm LIGHT WEIGHT ALUMINUM CARTRIDGE CASE



II. CASE DESCRIPTION

The cartridge case design which evolved from this and previous developments is depicted in Figure 2 (Drawing #00019-003, Rev. D).

The case was manufactured from 10B22 hot-rolled steel rod using a series of metal working, metal machining and heat-treating operations and procedures.

When these operations were completed, the case was final inspected, electro-zinc plated, and the exterior surfaces coated with a Northern LX1060 type varnish to enhance the extracting characteristics of the finished case.

A study of the case drawing shows that all dimensions are applicable prior to the administration of the two final protective finishes.

This was done to aid in the inspection of the finished case. It has been Amron's experience that discrepancies on gaging techniques can exist after the application of varnishes to exterior surfaces of cartridge cases. To eliminate this possibility, case was dimensioned and manufactured to dimensions which would prevail prior to the application of the final protective finish.

Hardness profiles of the different hardness zones present in the heat-treated steel case is depicted in either the C, N, or T hardness scales to avoid error when measuring the proper hardness at the different locations within the sidewall of the case.

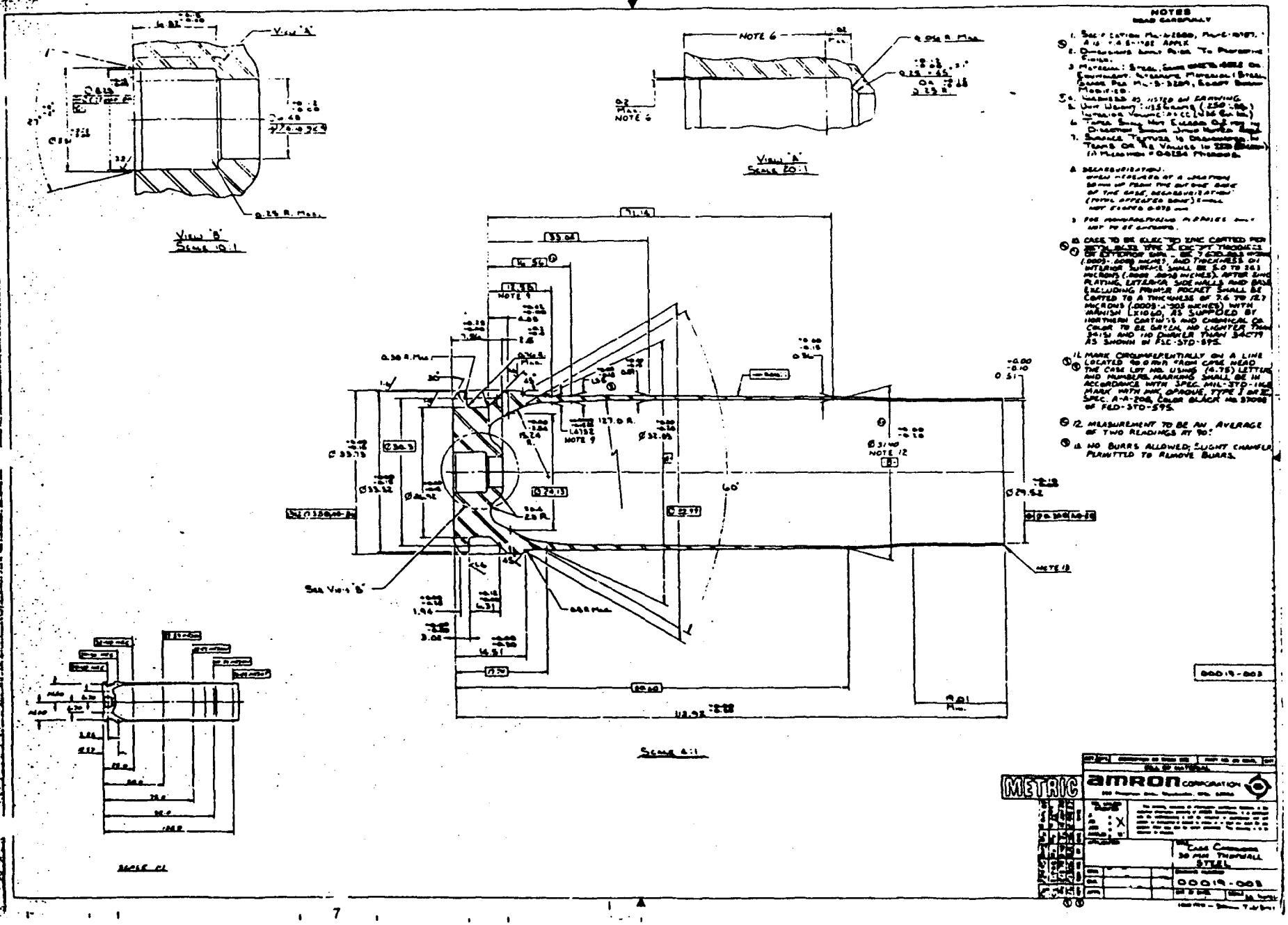
Basic geometry of the outside case envelope closely simulates that of the aluminum case except for the shoulder area which is more pronounced. This configuration is caused by the thin sidewalls of the case in the mouth area. Considering the mouth inside diameter is controlled by the projectile base diameter, the case must be more drastically tapered in this area to ensure the proper inside diameter at the mouth of the case.

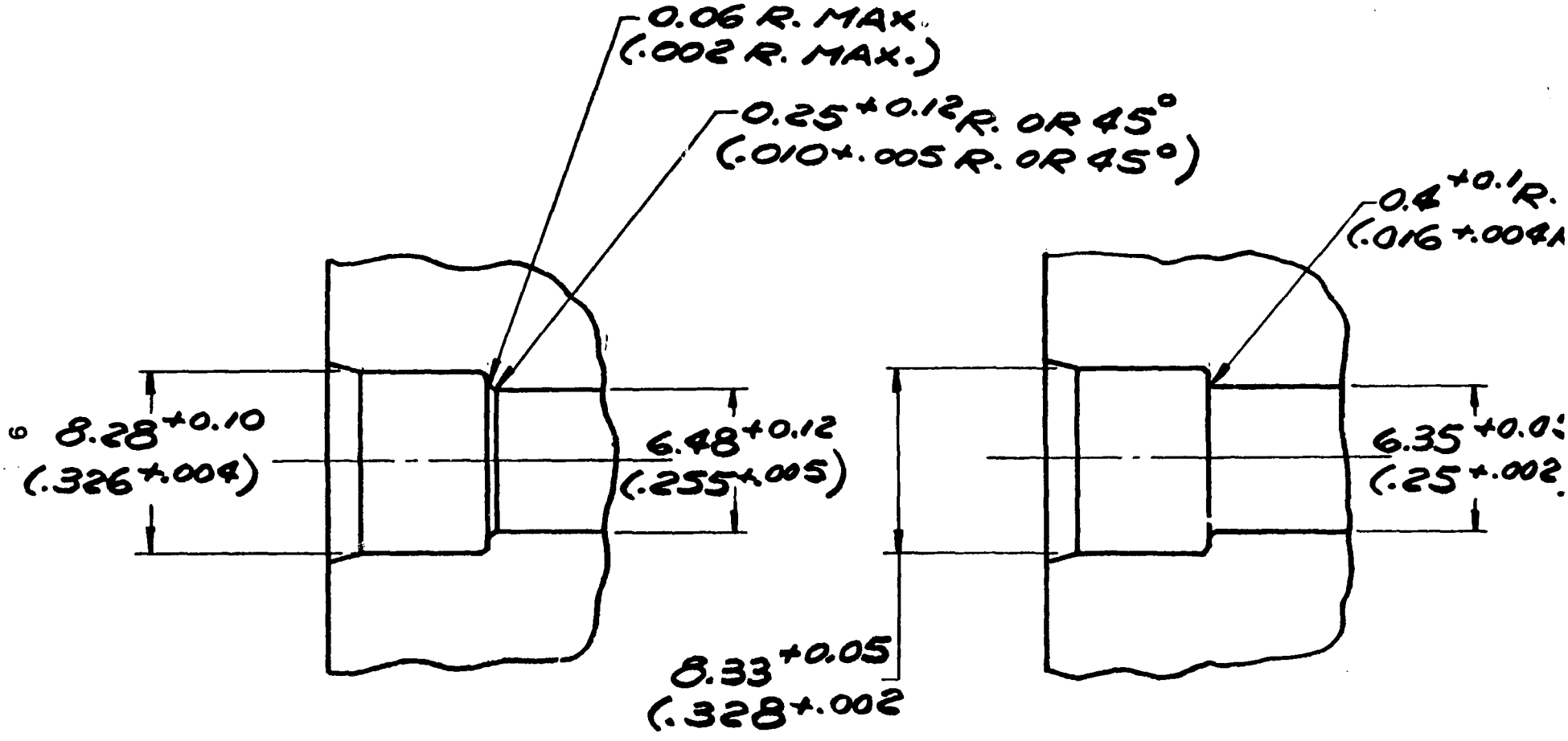
The primer pocket has been designed to accept either the PA520, M52A3 electric, or the M36A2 percussion primers.

A difference in primer pocket configuration and flash tube hole dimensions and tolerance between the aluminum and steel case as shown in Figure 3 does exist.

This change is necessitated by the different types of heat-treatment procedures which are used to achieve the required case hardness profile from the two different materials used to manufacture the cartridge case.

FIGURE 2 - 30mm THINWALL STEEL CARTRIDGE CASE





STEEL CASE

00019-003 - Rev. D

ALUMINUM CASE

00018-001 - Rev. E

FIGURE 3. PRIMER POCKET DIMENSIONAL COMPARISON

The manufacture of the steel case dictates that the primer pocket must be incorporated into the base of the case prior to the harden and quench heat-treating operation. If this operation was not performed at this time, base hardness achieved during the heat-treating operation would make machining very difficult.

In contrast, the hardness of the aluminum case does not achieve characteristics which cannot be machined after the heat-treating operation. In fact, machining is recommended after a hardening heat-treat operation on aluminum type products.

Dimensional changes in the head section of the steel case during heat treatment are also affected by the following parameters:

a. Physical characteristics of the starting stock
b. Temperature differential in the hardening furnace
c. Temperature differential in the quench media
d. Amount of cold work induced into the area of the primer pocket during fabrication.

These parameters dictate that steel case manufacturing requires a 0.10mm minimum tolerance on the primer pocket diameter to assure the primer pocket dimension will be within print tolerance at final inspection.

It should be stated at this time that during all the tests that were conducted under this development, at no time could any discrepancies in the primer pocket area be detected with the 0.10mm tolerance on the primer pocket diameter.

Consideration must also be given that the proven 20mm M103A1 steel cartridge case uses the identical primer pocket geometry and tolerances. This case which is used on M50 type ammunition uses either the M36A2 or M52A2 primer. To Amron's knowledge, no problems in loading or use caused by the case primer pocket geometry have ever been recorded.

III. CASE MATERIAL

Conventional steel cartridge cases such as the 20mm M103A1 use 1030 carbon steel in the form of plate or rod as a starting material. If thinwall steel cases were made from the same material, additional drawing operations with intermediate anneals would be required to reach the thinner walls desired, due to the increase in carbon content.

Steel for a cartridge case of thinwall design must also have the following several important characteristics:

1. High Strength

   To contain the chamber pressure in the gap between the bolt face of the gun and gun barrel while withstanding the extraction force in the rim area caused by the expansion of the case after firing.

2. Good Formability

   To maintain uniform material flow as the metal is shaped from a short, solid cylinder to a long, hollow cylinder with a relatively thin wall.

3. Good Machinability

   To facilitate high production rate machining equipment while still being able to maintain the tight tolerance required on several base dimensions.

4. Low Cost

   To achieve a competitive structure.

In 1975 Amron conducted a study to identify the best steel to use for a thinwall type cartridge case.

Low carbon steels with a small addition of boron were determined to be very promising. These steels feature the high strength, good extrudability, good machinability and uniform response to heat treatment at a low cost. Although 1030 was judged to be acceptable if additional operations were to be added to the manufacturing sequence, a 10B22 grade steel was eventually selected as the preferred starting material.

It was concluded that by lowering the carbon content to this level, additional cold working could be induced into the material before in-process annealing would be required.

With a reduction in carbon content, a lower maximum hardness and a shallower depth of hardening was also realized. The lower carbon content did allow for the effective use of boron as an alloying agent to improve the hardenability of the steel beyond that of a non-boron, modified 1030 steel. By adjusting the heat-treat parameters accordingly, the lower carbon, boron-modified steel allowed for easier manufacture while meeting all the final hardness requirements.

The cases for this development were made using hot-rolled, aluminum-killed, fine-grain, cold-extrusion quality 10B22 steel purchased to ASTM A576 specification with the exception of chemical analysis, which was modified, as shown in Table 1.

TABLE 1

Chemical Composition of 10B22 Steel

Element	ASTM A576	Amron Purchase Specification
C	.18 - .23%	.18 - .23%
Mn	.70 - 1.00%	.70 - 1.00%
P	.040% Max.	.025% Max.
S	.050% Max.	.020% Max.
Si	.10% Max.	.10% Max.
B	.0005% Min.	.0005% Min.

It can be seen that Amron requests tighter control on the tramp elements, sulphur and phosphorus. It has been Amron's experience that if these elements are not controlled, inclusions will form in the steel that will adversely affect the toughness of the steel.

Other parameters which controlled the procurement of steel for this program are depicted in Amron's Purchase Specification for hot-rolled, carbon steel for cartridge case, 30mm thinwall, document number PS-1076-30mm Thinwall Steel, Rev. A, dated 17 August 1989. (See Attachment 1.)

IV. PREPARATION OF RAW MATERIAL

Hot-rolled carbon steel rod, which is used as the starting material for the manufacture of the thinwall steel cartridge case, may at times have surface defects inherent to the material due to its method of manufacture.

These defects appear in the form of splits, seams, or decarburization on the outer surfaces of the bar stock and can be deleterious to the manufacture of a quality cartridge case.

To assure that these imperfections are removed, a "turn and burnish" operation was performed which removed approximately .080 inches of material per side on the bar stock diameter prior to being released for production.

V. HEAT TREATMENT

The performance requirement of the different sections of a cartridge case determines what levels of hardness must be achieved during heat-treatment operations.

A high level of hardness is required in the base section to provide the high strength needed to withstand set-back forces on the bolt face of the gun and exposed areas of the case during firing. The sidewall has conflicting requirements. A low level of hardness is needed to provide ductility to the case sidewall; yet a high level of hardness is needed to provide for case contraction after the case has expanded with the barrel during firing. High contraction is needed to minimize extraction forces due to interference of the case with the gun chamber. A low level of hardness is required in the mouth area to provide ductility to enable the projectile to be crimped to the cartridge case.

A. Hardening and Temper

To achieve these required hardnesses, a high temperature single tube hardening furnace employing an exothermic generator which produced pure nitrogen as its atmosphere was employed. The atmosphere which was generated blanketed the cases during the heating cycle, preventing oxidation and decarburization of the parts being heat-treated.

To obtain the best mechanical properties, it was necessary to completely (or nearly so) transform to martensite the austenitic micro-structure of the steel.

This transformation is best assured utilizing a quench mechanism designed exclusively for this operation. In the quench portion of heat-treat cycle, the part falls into an annular fixture where it is held in a fixed position while a jet of quenchant is administered.

This procedure and fixture ensures the two most important parameters of heat-treat quenching are met; namely, severity and uniformity of quench.

Once hardened, the part was drawn back or tempered to the proper required hardness range. A localized anneal was performed at the mouth area of the case to restore adequate ductility to permit crimping of the projectile to the case.

VI. MANUFACTURING PROCESS

The chosen method of manufacture for producing cartridge cases for this development is known as the "R.E.D." method.

The method entails using hot-rolled steel rod as the starting material, extruding a shallow cup, then draw and ironing the cup into a closed end cylindrical tube prior to heading out and machining the base configuration as shown in Figure 4.

A detailed listing of all the required operations is shown in Table 2, which is followed by a brief description of each operation.

FIGURE 4 - SEQUENCE OF OPERATIONS

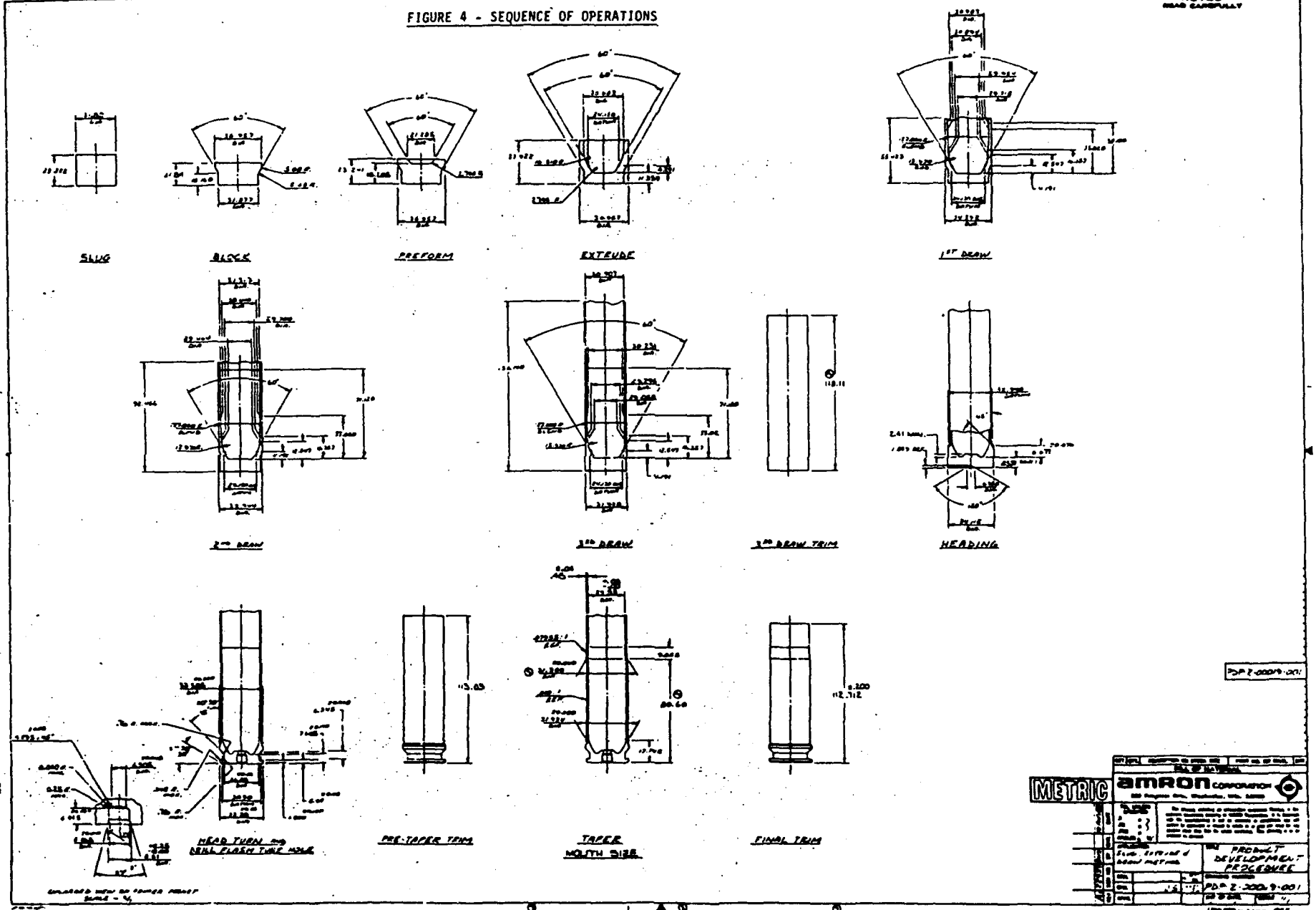


TABLE 2

MANUFACTURING SEQUENCE

OPERATION NO.	DESCRIPTION	MACHINE DESCRIPTION
010	Receive and Check Order	
020	Receiving Inspection	
030	Saw Slug	Wagner Saw Model KMLN2
040	Preanneal Wash	Metalwash Comb. Anneal Furnace
050	Anneal Slugs	Surface Comb. Anneal Furnace
060	Phosphate/Lube/Dry	Ransohoff (7) Stage/Dry
070	Block	400 Ton Press
080	Preform	400 Ton Press
090	Preanneal Wash	
100	Anneal	
110	Phosphate/Lube/Dry	
120	Extrude	400 Ton Press
130	Preanneal Wash	
140	Anneal	
150	Phosphate/Lube/Dry	
160	1st Draw	Bliss 85-1/2
170	Preanneal Wash	
180	Anneal	
190	Phosphate/Lube/Dry	
200	2nd Draw	Bliss 85-1/2
210	Preanneal Wash	
220	Anneal	
230	Phosphate/Lube/Dry	
240	3rd Draw	Bliss 85-1/2
250	3rd Draw Trim	V&O Trimmer
260	Indent and Heat	Danly K-400
270	Head Turn	Turret Lathe
280	Preharden Wash	Ransohoff
290	Harden	Surface Comb. Tube Furnace
300	Temper	Furnace
310	Body Anneal	
320	Pretaper Trim	V&O Trimmer
330	Pickle and Soap Coat	Ransohoff
340	Taper	Bliss 86
350	Final Trim	Lathe
360	Mouth Size	Ransohoff

MANUFACTURING SEQUENCE - CONTINUED

OPERATION NO.	DESCRIPTION	MACHINE DESCRIPTION
370	Final Inspection Dimensional	
380	Zinc Plate	LaSalco
390	Lacquer	Binks
400	Final Inspect	
410	Pack & Ship	

OPERATION NO.	OPERATION DESCRIPTION
010	Receive and Check Order
	When material is received from the "bar turner" where the outside diameter has been turned and burnished to remove any surface imperfections, it is checked against shipping documents. A count of material received is forwarded to the Inspection Department which institutes an inspection plan based on quantity of material received.
020	Receiving Inspection
	Received material is checked against the parameters set forth in the manufacturing process. A dimensional check is made to assure that the rod has been turned and burnished to the correct diameter. A visual check is also made of surface condition and straightness of the received rod. To assure that the proper chemistry exists, several sample sections are sent to a metallurgical laboratory for chemical analysis.
030	Saw Cut
	The 20-ft. random length steel rods are cut to exacting slug requirements. Dimensional control of the length of cut and perpendicularity of the saw cut face to the outside diameter are imperative for good cartridge case manufacture.
	A final check of the weight of the saw cut blanks assures that adequate starting material to manufacture the case is available.
040	Preanneal Wash
	To assure that all foreign impurities are removed from the surfaces of the slugs prior to anneal, the slugs are processed through a preanneal washer.
050	Anneal
	To acquire maximum ductility in the slug prior to the extruding operation, and to remove any residual stresses which could be encountered during the manufacture of the rod, the washed slugs are annealed in a belt-type, continuous annealing furnace at 1300°F. Time at heat is controlled by the movement of the mesh belt.

060 Phosphate, Lubricate and Dry

To remove any annealing oxidation and to provide an adequate substrate for depositing a soap lubricant, annealed slugs are processed through a seven stage rotary coater.

070 Block

Coated slugs are introduced to the first forming operation. Slug is formed in a 400-ton, straight side press into a preformed blank having a precise outside configuration, larger on the top, smaller on the bottom. This configuration sets the shape for future draw operations.

080 Preform

To provide for a location point for the entry of the extruding punch during the extrude operation, the blocked part is indented on the front face of the large diameter. This indentation must be perfectly concentric to the outside diameter of the part to ensure reasonable wall variation tolerance will be achieved after the extrude operation.

090 Preanneal Wash

100 Anneal

110 Phosphate, Lubricate and Dry

To remove all cold work stresses and return the preformed indented blank to a soft condition with adequate lubrication, the blanks are processed through the preanneal-anneal-phosphate coat, lubricate and dry operations prior to the extrude operation.

120 Extrude

The indented blank is placed into a die confining the outside envelope of the blank. A punch is driven into the indented configuration on the front face of the large diameter. Considering the outside envelope is confined, material will flow up the punch as it is pushed deeper into the preformed blank leaving a configuration suitable for the drawing operation.

130 Preanneal Wash

140 Anneal

150 Phosphate, Lubricate and Dry

Substantial cold working stresses have been introduced into the preformed indented blank during the second extruding operation. The blank, therefore, must once more be softened to allow for additional metal working operations to continue. This is again accomplished by sending the blank through the preanneal, anneal and phosphate, lubricate and dry operations.

160 1st Draw

A series of draw operations are now incorporated into the manufacturing process. During the first of these operations, the sidewall of the extruded blank is thinned by reducing the outside diameter of the blank. This operation also is the starting point for controlling the final wall geometry of the finished cartridge case.

170 Preanneal Wash

180 Anneal

190 Phosphate, Lubricate and Dry

Again, substantial cold worked stresses have been introduced to the sidewalls of the drawn blank. To return the blank to a soft condition, to permit additional metal working operations to continue, the drawn blank must be processed through the preanneal wash, anneal and phosphate, lubricate and dry operation.

200 2nd Draw

Continuing with the reducing of the blank sidewalls and achieving the desired cross-sectioned sidewall geometry, the first drawn part is introduced to the second draw operation. During this operation, the outside diameter is further reduced in size, thereby giving the sidewalls a thinner cross section.

210 Pre-Anneal Wash

220 Anneal

230 Phosphate, Lubricate and Dry

The second drawn part is placed through the preanneal wash, anneal and phosphate, lubricate and dry operations for the final time to eliminate cold worked stresses. These operations again prepare the second drawn blank for the final third draw operations.

240 3rd Draw

During the third draw operation, final sidewall geometry and wall variation is accomplished. This is achieved by proper draw punch and ring configuration interface.

250 3rd Draw Trim

To eliminate an irregular top, which can be achieved on the open end during the draw operations, the drawn part is trimmed to a predetermined overall length. This operation also eliminates any end grain in the drawn blank, thereby enhancing the quality of the cartridge case.

260 Indent and Head

Following the final draw operation, the base of the drawn case must be increased to a dimension in excess of the belt diameter of the finished cartridge case. This is accomplished by subjecting the drawn case to a 400-ton, knuckle joint press with a rotary table. In three consecutive strokes of the press, and in three separate operations, the base of the case is expanded, internal geometry at base of case set, and the indentation for the primer pocket introduced.

270 Head Turn

Preceding the hardening operation, the headed case is subjected to a machining operation. At this time the belt diameter, datum length, flange diameter and thickness, extractor groove diameter and width, flash hole diameter and primer pocket diameter and depth are achieved. It must also be remembered that the case will next be subjected to a thermal heat-treatment procedure. During this operation, all machined dimensions will change slightly due to the temperatures involved during the heat-treat cycle. Dimensions must, therefore, be machined into the cartridge case with allowances made for these changes which will occur.

280 Preharden Wash

To remove all machinining oils and foreign material which may be adhering to the machined case prior to heat treating, the case is washed in a spray type washer.

290 Harden

Hardness requirements are heat treated into the head and sidewall of the head-turned case. This is accomplished by heating the case to 1650°F in a pusher-type, hardening furnace, then quenching in a brine solution.

300 Temper

Final hardness requirement is accomplished by tempering the hardened case at approximately 700°F.

310 Body Anneal

To aid in the tapering operation and to acquire final hardness requirements at the mouth of the cartridge case, the mouth of the case is annealed by passing the case over a gas flame which heats the mouth of the case to 1200°F for a distance of 1-1/2 inches back from the open end of the case.

320 Pretaper Trim

Preceding the tapering operation, cases are subjected to a trim operation. This is done to remove any dents or nicks which may have occurred at the mouth of the case during the heat-treating operation. If this operation were not incorporated, excessive tapering scrap would be encountered.

330 Pickle and Soap Coat

A slight pickling operation is incorporated into the process to remove any heat-treating oxidation residue which may be present on the cartridge case. A light coating of soap which aids in the tapering operation is also added during this operation.

340 Taper

Following the soap coating operation, the case is subjected to a tapering operation which produces the final outside geometry of the case.

350 Final Trim

The final metal removing operation is accomplished by trimming the case to proper overall length.

360 Mouth Size

To ensure the proper mouth inside diameter will be met, a final mouth sizing or plugging operation is incorporated into the process. This is accomplished by placing an expanding plug into the mouth of the case, thereby sizing and rounding the case mouth.

370 Final Inspection Dimensional

Prior to the application of a final protective finish and a coating of lacquer, cases are inspected for dimensional characteristics. If all dimensions are within AQL levels, cases are processed to the zinc operation.

380 Zinc Plate

Prior to the application of a final case coating, cases are zinc plated.

390 Lacquer

To assist in extracting a spent cartridge case from the gun chamber, the exterior surfaces of the finished case are sprayed with a coating of LX-1060 Northern lacquer. Once adequately applied, finish will be cured by processing the part through a curing oven.

400 Final Inspection

To assure that the finish case will fit into the gun chamber, cases are gaged 100% for maximum profile.

410 Pack and Ship

Inspected, lacquered cases are placed in partitioned boxes; 180 per box, prior to shipment, to a load facility.

VII. COATING STUDY

A. Introduction

During initial development of the 30mm thinwall steel cartridge case, the exterior surface was coated with a thermo setting epoxy-amino resin varnish supplied by Dr. W. Mader, AG 8956 Killwagen (Boden) Switzerland. The material was a Suparal baking enamel paint with an olive gloss transparency number 350.8.7.0001 and reduced to a spray viscosity with thinner number 990.0.0.0223, or a reducer number 990.425 supplied by De Beers Laboratories, Incorporated.

The thickness coating of the external application in its dry state was between 12 and 20 microns.

In addition to the external application, the internal surfaces were coated with a thickness of 5 to 12 microns dry of a Suparal enamel semi-gloss, black in color, number 358.7.2.0004 reduced to spray viscosity using the same thinner or reducer as stated above. The above coatings, when applied to the cartridge case surfaces, met all environmental requirements and functioned well when the case was fired.

To eliminate the "off-shore" procurement of the above coating, it was realized that a substitute coating manufactured in the USA should be investigated.

To determine if this could be accomplished, a coating study was conducted as an integral part of this developmental contract.

After considerable investigation of coatings, the following two were chosen as candidates to be tested as a possible replacement coating for the Mader lacquer:

1. De Beers varnish over a zinc plate and chromate base

   Application

   The entire cartridge case was zinc-plated per Specification ASTM B633, Type II. Plating thickness on the external surface of the case was 7.6 to 20.3 microns. Plating on internal surfaces ranged from 5 to 20.3 microns. Once plating was completed, external sidewalls and base of cartridge case, excluding the primer pocket and flash hole, were coated with a thickness of 8 to 18 microns of a polyimide-amide, hot, hard varnish with an additive of 30% PTFE. Curing of

the varnish was accomplished by exposing the coated case to a furnace set at 465°F ± 10°F for a cure time of 6 to 7 minutes. This coating is currently being used on the 25mm steel Bushmaster cartridge case. Approved source for the coating is the Midland Division of the Dexter Corporation.

2. Northern varnish over a zinc plate and chromate base

Application

The entire cartridge case was zinc-plated per Specification ASTM B633, Type II. Plating thickness on the external surface of the case was 7.6 to 20.3 microns. Plating on the internal surfaces ranged from 5 to 20.3 microns.

Once plating was completed, external sidewalls and base of cartridge case, excluding the primer pocket and flash hole, were coated with a thickness of 7.6 to 12.7 microns of a Northern Coating and Chemical Company varnish, Type LX-1060 (green).

Curing of the varnish was accomplished by exposing the coated case to a furnace temperature of 475° ± 10° for a cure time of 6 - 7 minutes.

Approved source for this coating is the Northern Coating and Chemical Company located in Menominee, Michigan.

This coating was developed for use on the 30mm GAU-8 thinwall steel cartridge case developed by Battelle Research Laboratories, Columbus, Ohio, and Amron Corporation.

In addition to applying the LX-1060 lacquer over the zinc-plated substrate, a quantity of cases were also coated with the LX-1060 lacquer over a phosphate-coated substrate. This was done to evaluate the effect of the LX-1060 lacquer applied over two different type substrates after test firing.

B. Test Plan

To evaluate the effects of the various coatings on the cartridge case during firing, a test plan as shown in Attachment 2 was implemented.

A summary of this plan relates that a 30mm thinwall steel cartridge case coated with Mader lacquer and loaded with a propellant, which would produce an excessive pressure condition in the cartridge when fired, be used. This excessive pressure under flex breech testing would produce a moderate to heavy "necking" condition on the sidewall of the cartridge case.

Severity of stretch in relation to internal pressure and force required to extract the spent cartridge case from the chamber of the weapon after firing would be recorded and analyzed.

Parameters which are produced under the above conditions would be used as the base line results when testing the new coatings under identical conditions.

C. Flex Breech Mechanism

When a cartridge is fired in an automatic weapon, the force on the bolt face of the weapon is the sum of the rearward pressure force less the case wall frictional force.

If the bolt mechanism is relatively flexible, and the case sidewall friction high, during firing, the case sidewall can be stretched beyond its elastic limit; thereby, causing a transverse rupture on the sidewall of the spent cartridge case.

To simulate the flexibility of an automatic gun breech under Mann barrel testing conditions, a "flex" breech mechanism is used in conjunction with the Mann barrel.

This mechanism, as shown in Figure 5 operates on the following principle: Copper washers of known height and hardness are placed over a stepped pressure plate. The difference between the height of the washer and height of the step on the pressure plate will determine the amount of set-back generated by the cartridge during firing.

To determine the amount of force being generated by the firing of the cartridge on the breech block of the weapon, the washers used with the flex breech can be calibrated and the amount of washer upset in relation to the amount of force required to produce the upset recorded.

Washers used for the test can then be measured before and after firing and the amount of force being encountered by the breech block determined by the amount of washer upset.

D. Test Results

Table 3 is a tabulation of the data acquired during the coating study tests.

Analysis of the test results indicates that the performance of the Northern LX-1060 varnish over either a phosphate substrate per Specification TT-C-490 or a zinc and chromate substrate per Specification ASTM B633 compared favorably against results achieved using the Mader lacquer #358.7.2.0004 over a phosphate substrate.

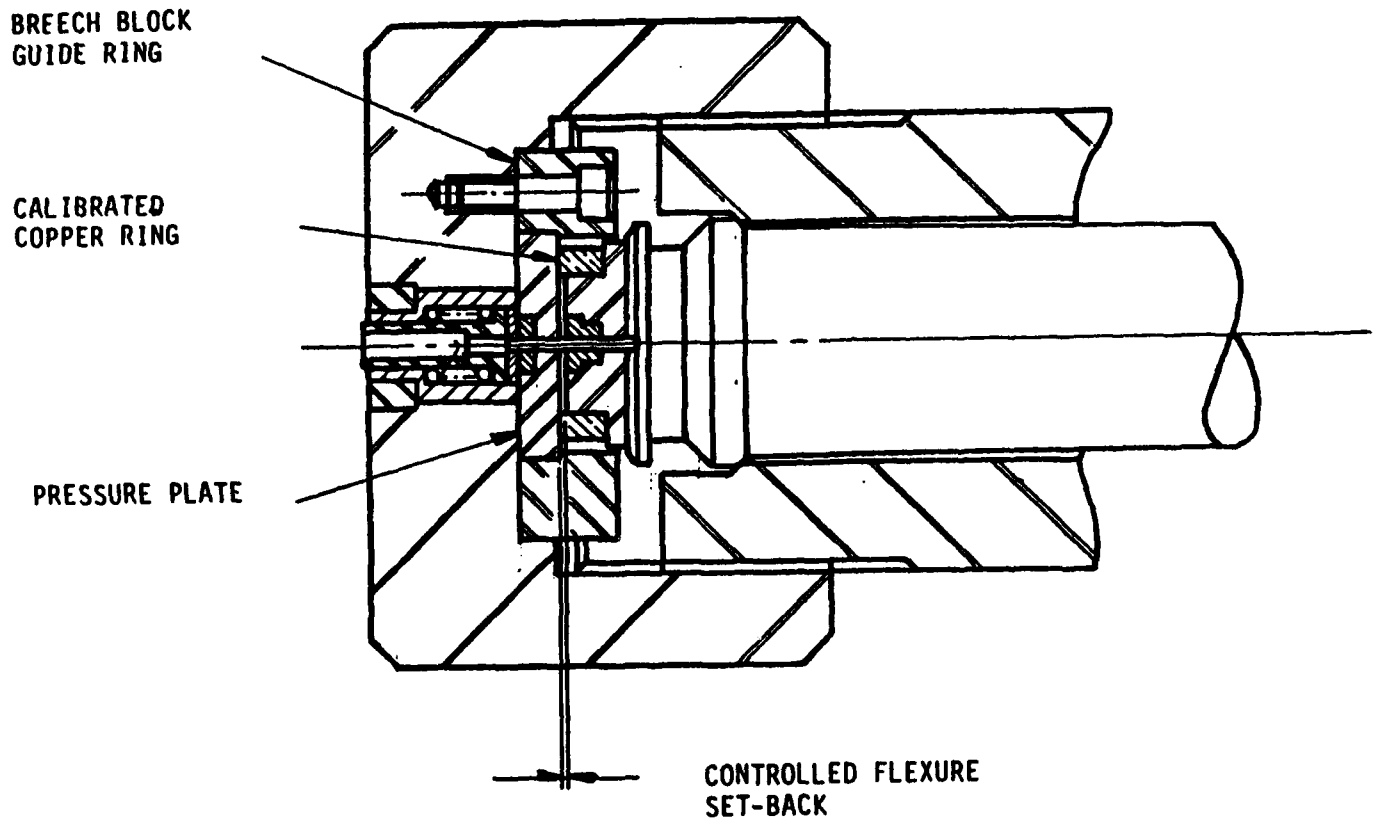


FIGURE 5. FLEXIBLE BREECH MANN BARREL MECHANISM

Tests were done using the "flex-breech" method of accomplishing case setback in the 30mm ADEN test Mann barrel. Setbacks up to .069 inches were encountered with no detrimental effect to the cartridge cases tested using the above-mentioned coatings.

Cases coated with the Midland-Dexter coating over a zinc and chromate substrate, however, showed signs of case distress after approaching a setback of .035 inches and a complete case separation once case setback of .050 inches was achieved.

Based on these results and the need to eliminate the off-shore procurement requirement necessary for the acquisition of the Mader lacquer, it is recommended that the LX-1060 varnish over a zinc and chromate substrate be utilized. This coating is a more than adequate substitute for the Mader lacquer.

TABLE 3. COATING EVALUATION

30MM THINWALL STEEL CARTRIDGE CASE

COATING	TEST	CASE PRESSURE (PSI)	RING WEIGHT START	RING WEIGHT FINISH	SET BACK	RESULTS
MADER LACQUER PHOS. COAT	1	44,100	.260	.208	.052	NO ANOMALIES NOTED
	2	43,000	.260	.207	.053	" " "
	3	43,100	.265	.208	.057	" " "
	4	42,000	.270	.209	.061	" " "
	5	41,500	.270	.210	.060	" " "
NORTHERN LX1060 ZINC	1	43,500	.260	.208	.052	NO ANOMALIES NOTED
	2	44,200	.260	.201	.059	" " "
	3	43,000	.265	.208	.057	" " "
	4	45,000	.270	.208	.062	" " "
	5	41,000	.270	.201	.069	" " "
NORTHERN LX1060 PHOS. COAT	1	43,900	.260	.209	.051	NO ANOMALIES NOTED
	2	43,000	.260	.201	.059	" " "
	3	42,500	.264	.208	.056	" " "
	4	41,000	.270	.208	.062	" " "
	5	39,000	.270	.201	.069	" " "
MIDLAND DEXTER ZINC	1	44,500	.260	.209	.051	HEAVY STRETCH IN NECK AREA
	2	43,900	.260	.210	.050	LIGHT " " " "
	3	43,600	.260	.210	.050	HEAVY " " " "
	4	41,800	.260	.209	.051	" " " " "
	5	43,600	.260	.208	.052	COMPLETE SEPARATION OF NECK FROM BODY

II. BALLISTIC AND ENVIRONMENTAL TEST PROGRAM OVERVIEW

To prove the integrity of the designed cartridge case, a two-phase manufacturing and test program was initiated.

Phase I of the program was dedicated to the manufacture and testing of 869 cartridge cases.

Phase II provided provisions for the correction of any discrepancies which may have occurred during Phase I testing.

Once discrepancies, if any, were corrected, an additional 7,200 cases would be manufactured. The initial phase of the Phase II test program was to fire 227 cartridge cases under a lot acceptance test program. The second phase was the firing of an additional 1,741 cartridge cases under a qualification test program.

X. BALLISTIC AND ENVIRONMENTAL TEST PROGRAM - PHASE I

A. Phase I - Tests and Results

Table 4 is a tabulation of the number of cartridge cases tested at the various required tests. A description of each of the tests performed and the results achieved during the test follows the tabulation.

A summary of the ballistic data achieved during Phase I testing can be found in Table 5. Table 6 depicts a summary of the environmental test data.

B. Conclusions

After analyzing the data accumulated during Phase I testing for ballistic and environmental requirements, the data indicated that the case performed extremely well for all tests except for the temperature and humidity requirement. During testing for this requirement, action times in excess of five (5) milli-seconds were experienced indicating that the case had failed to pass this requirement.

TABLE 4

PHASE I - TEST PROGRAM

SUMMARY

TEST	CONDITION	WEAPON	QUANTITY	ROUND TYPE
Pressure, velocity action time	Ambient	M-230 Mann	45	M-788
Pressure, velocity action time	Hot	M-230 Mann	15	M-788
Pressure, velocity action time	Cold	M-230 Mann	15	M-788
Water proofness	Ambient	M-230 Mann	20	M-788
Salt fog	Ambient	M-230 Mann	20	M-788
High pressure	Ambient	M-230 Mann	20	M-788
Pressure, velocity action time	Ambient	Aden Mann	10	M-788
Pressure, velocity action time	Hot	Aden Mann	10	M-788
Pressure, velocity action time	Cold	Aden Mann	10	M-788
Aircraft vibration	-	M-230 Mann	20	M-788
Temperature-humidity	-	M-230 Mann	35	M-788
Extreme temperature storage	-	M-230 Mann	35	M-788
Transportation vibration	-	M-230 Mann	35	M-788
Function & casualty/ weapon compatibility	Ambient	M-230 Auto	100	M-788
Function & casualty/ weapon compatibility	Hot	M-230 Auto	100	M-788
Function & casualty weapon compatibility	Cold	M-230 Auto	100	M-788
Debulleting	Ambient	M-230 Auto	25	M-788
Debulleting	Ambient	Aden Auto	125	M-788
Bullet pull	Ambient	-	7	M-788
Temperature humidity Retest	-	M-230 Mann	122	M-788

TEST GROUP: 30mm T.W.S.C.C. - Phase I

TEST OBJECTIVE: Pressure, Velocity and Action Time TD-01 @ 21° C

TEST ITEM: 30mm T.W.S.C.C.

QUANTITY: 45

PROCEDURE: Test groups were fired in an M230 MANN Barrel, at a rate not to exceed three minutes between rounds.

Ammunition was conditioned a minimum of 24 hours @ 21° C before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AV. PRESSURE	STD. DEV.
3 Apr 86	15 Rds.	804.6 M/S	3.18 M/S	287.2 MPa	4.70 MPa
7 Apr 86	15 Rds.	803.6 M/S	3.00 M/S	285.7 MPa	5.03 MPa
14 Apr 86	15 Rds.	805.5 M/S	2.87 M/S	290.9 MPa	7.22 MPa

There were no case anomalies observed.

Action times recorded resulted in no action times that exceeded four (MS).

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Phase I

TEST OBJECTIVE: Pressure, velocity, and action time (TD-01) @ 71° C

TEST ITEM: 30mm T.W.S.C.C.

QUANTITY: 15

PROCEDURE: Test group was fired in an M230 MANN Barrel, at a rate not to exceed three minutes between rounds.

Ammunition was conditioned @ 71° C for a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AV. PRESSURE	STD. DEV.
9 April 86	15 Rds.	824.6 M/S	4.28 M/S	316.1 MPa	8.96 MPa

There were no case anomalies observed.

Action times recorded resulted in no action times that exceeded four (MS).

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Phase I

TEST OBJECTIVE: Pressure, velocity and action time TD-01 -54° C

TEST ITEM: 30mm T.W.S.C.C.

QUANTITY: 15

PROCEDURE: Test group was fired in an M230 MANN Barrel, at a rate not to exceed three minutes between rounds.

Ammunition was conditioned @ -54° C for a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AV. PRESSURE	STD. DEV.
9 April 86	15	777.0 M/S	3.84 M/S	265.7 MPa	9.89 MPa

There were no case anomalies observed.

Action times recorded resulted in no action times that exceeded four (MS).

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Phase I

TEST OBJECTIVE: Pressure, velocity and action time waterproofness (TD-18) @ 21° C.

TEST ITEM: 30mm T.W.S.C.C.

QUANTITY: 20

PROCEDURE: Test group was fired in an M230 MANN Barrel, at a rate not to exceed three minutes between rounds.

Ammunition was conditioned for waterproofness per (TD-18) and conditioned @ 21° C for a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AV. PRESSURE	STD. DEV.
10 April 86	20	802.5 M/S	3.08 M/S	287.3 MPa	6.63 MPa

There were no case anomalies observed.

Action times recorded resulted in no action times that exceeded four (MS).

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Phase I

TEST OBJECTIVE: Pressure, velocity and action time
Salt Fog (Spray) (TD-19) @ 21° C

TEST ITEM: 30mm T.W.S.C.C.

QUANTITY: 20

PROCEDURE: Test group was fired in an M230 MANN Barrel, at a rate not to exceed three minutes between Rounds.

Ammunition was conditioned per (TD-19) Salt Fog for 48 hours and conditioned @ 21° C for a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AV. PRESSURE	STD. DEV.
23 April 86	20	805.0 M/S	3.06 M/S	293.0 MPa	7.94 MPa

There were no case anomalies observed.

Action times recorded resulted in no action times that exceeded four (MA).

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Phase I

TEST OBJECTIVE: Pressure, velocity and action time
Overpressure @ 21° C 55.0 gram charge

TEST ITEM: 30mm T.W.S.C.C.

QUANTITY: 20

PROCEDURE: Test group was fired in an M230 MANN Barrel, at a rate not to exceed three minutes between rounds.

Ammunition was conditioned @ 21° C for a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	MIN. PRESSURE	MAX. PRESSURE
11 April 86	20 Rds.	406.8 MPa	449.6 MPa

There were no case anomalies observed.

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Phase I

TEST OBJECTIVE: Pressure, velocity and action time
Aden MANN Barrel @ 21° C

TEST ITEM: 30mm T.W.S.C.C.

QUANTITY: 10

PROCEDURE: Test group was fired in an Aden MANN Barrel, at a rate not to exceed three minutes between rounds.

Ammunition was conditioned @ 21° C, a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AV. PRESSURE	STD. DEV.
5 March 86	10 Rds.	801.5 M/S	5.90 M/S	264.8 MPa	11.4 MPa

There were no case anomalies observed.

Action times recorded resulted in no times that exceeded four (MA).

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Phase I

TEST OBJECTIVE: Pressure, velocity and action time
Aden MANN Barrel @ 71° C

TEST ITEM: 30mm T.W.S.C.C.

QUANTITY: 10

PROCEDURE: Test group was fired in an Aden MANN Barrel, at a rate not to exceed three minutes between rounds.

Ammunition was conditioned @ 71° C for a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AV. PRESSURE	STD. DEV.
5 March 86	10 Rds.	825.1 M/S	4.3 M/S	299.6 MPa	11.4 MPa

There were no case anomalies observed.

Action time recorded resulted in no action times that exceeded four (MS).

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Phase I

TEST OBJECTIVE: Pressure, velocity and action time
Aden MANN Barrel @ -54° C

TEST ITEM: 30mm T.W.S.C.C.

QUANTITY: 10

PROCEDURE: Test group was fired in an Aden MANN Barrel at a rate not to exceed three minutes between rounds.

Ammunition was conditioned @ -54° C for a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AV. PRESSURE	STD. DEV.
5 March 86	10 Rds.	785.9 M/S	5.1 M/S	249.9 MPa	12.45 MPa

There were no case anomalies observed.

Action times recorded resulted in no action times that exceeded four (MS).

TEST CONCLUSION: Cartridge Case passed

Test No: 30mm T.W.S.C.C. - Phase I

Description: Aircraft Vibration per MIL-STD-810C, Method 514.2 (Ref TD-30 Rev E)

Test Item: 30mm TP Cartridge with Steel Case

Quantity: 20

Procedure: Cartridges were tested in the M592 Ammunition container. The test items were linked and placed near the middle of the container. The balance of the container was filled with linked dummy or non-test TP cartridges (72 full container) to achieve normal pack tightness and weight. The loaded container was attached rigidly to the vibration fixture. Vibration testing was conducted in accordance with Procedure I, Category C, reference Table 514.2-III and Figure 514.2-3. Each test item was vibrated for 3 hours/axis (3) at -54C and +71C (18 hours total). Pre-conditioning time at each temperature was 8 hours minimum.

All test items were examined visually after the vibration exposure and any anomaly related to the steel case such as loose primers, loose projectiles, scratches, dents, etc. was noted. All test items were then subjected to ballistic tests in the M230 Mann Barrel wherein velocity, pressure, action time and MPS were measured.

RESULTS: There were no Aircraft Vibration related or ballistic anomalies observed. The ballistic data is summarized in Table 6.

CONCLUSION: Passed

Test No: 30mm T.W.S.C.C. - Phase I

Description: Temperature-Humidity per MIL-STD-331A, Test 105.1 (Ref TD-20 Rev E)

Test Item: 30mm TP Cartridge with Steel Case

Quantity: 35

Procedure: Cartridges were placed in the temperature humidity chamber horizontally on a chrome plated rack. The 28 day (2 cycle) test, as described in test 105.1, was conducted.

All test items were examined visually after 21 days (1 1/2 cycle) and after 28 days and any corrosive anomaly noted including photographic documentation. Five (5) test items were disassembled after the test and visually examined for evidence of internal moisture or corrosion. The remaining 30 test items were subjected to ballistic test in the M230 Mann barrel wherein velocity, pressure, action time and MPS were measured.

RESULTS: External examination indicated only slight corrosive residue at the primer and projectile interfaces, none was considered significant. Teardown of the 5 units showed corroded primer closure cups and discolored flashtube lacquer and tape seals. Primer resistance measured after disassembly (5 Units) ranged from 3200 - 8500 ohms or 10 - 20 times normal. Ballistically the rounds had normal pressure and velocity for post T&H firings, but several (10) had action times in excess of the 4 milliseconds requirement. The ballistic data is summarized in Table 6.

CONCLUSION: Failed due to action times greater than 4 milliseconds.

Test No: 30mm T.W.S.C.C. - Phase I

Description: Extreme Temperature Storage per MIL-STD-331A, Test 112.1 (Ref TD-24 Rev D)

Test Item: 30mm TP Cartridge with Steel Case

Quantity: 35

Procedure: Cartridges were placed in the temperature chamber horizontally. The 56 day storage test, as described in test 112.1 Procedure 1, was conducted.

All test items were examined visually and any corrosive or temperature anomaly effects noted. Five (5) test items were disassembled and components visually examined for anomalies. The remaining 30 test items were subjected to ballistic test in the M230 Mann barrel wherein velocity, pressure, action time and MPS were measured.

RESULTS: There were no extreme temperature storage or ballistic anomalies observed including the 5 disassembled. Resistance of all 35 units were checked after the storage test and found to be normal (range from 70 to 851 ohms). The ballistic data is summarized in Table 6.

CONCLUSION: Passed

Test No: 30mm T.W.S.C.C. - Phase I

Description: Transportation Vibration-Temperature per MIL-STD-331A, Test 119 (Ref TD-12 Rev E)

Test Item: 30mm TP Cartridge with Steel Case

Quantity: 35

Procedure: Cartridges were tested in the M592 Ammunition container. The test items were linked and placed near the middle of the container. The balance of the container was filled with linked dummy or non-test TP cartridges (72 full container) to achieve normal pack tightness and weight. The loaded container was attached rigidly to the vibration fixture. Vibration testing was then conducted as described in test 119, Procedure 1. Twelve (12) test units each were tested at -54C and +71C and eleven (11) tested at +21C.

All test items were examined visually after the vibration exposure and any anomaly related to the steel case such as loose primers, loose projectiles, scratches, dents, etc. were noted. Five (5) test items were set aside for disassembly. The remaining 30 test items were subjected to ballistic tests in the M230 Mann barrel at the same temperature that vibration occured wherein velocity, pressure, action time and MPS were measured.

RESULTS: There were no Transportation Vibration related or ballistic anomalies noted. Three (3) units were disassembled and no anomalies found. Resistance of the 5 units was normal ranging from 19 to 230 ohms. The ballistic data is summarized in table 6.

CONCLUSION: Passed

Test No : 30mm T.W.S.C.C. - Phase I

Description : Function & Casualty/Weapon Compatibility
(Ref TD-38 Rev C / TD-41 Rev F)

Test Item : 30mm TP Cartridges with Steel Case

Quantity : 300

Procedure : The test items were fired in the M230 Automatic Gun as follows:

Quantity	Ammo Temp	Burst Size
100	+21 C	25
100	-54 C	25
100	+71 C	25

Ammunition conditioning prior to firing was 2 hours minimum.

The following data was recorded:

...Muzzle velocity, burst rate, cooling time
...Metal parts security
...Anomalies in performance of ammo or weapon
...Case related anomalies such as primer leaks, loose primers, split cases, extractor tears, etc.

RESULTS: There were no ballistic or MPS anomalies observed. The ballistic data is summarized in Table 6.

CONCLUSION: Passed

Test No : 30mm T.W.S.C.C. - Phase I

Description : Debulleting - M230
(Ref TD-33 Rev C)

Test Item : 30mm TP Cartridges with Steel Case

Quantity : 25

Procedure : The test items were cycled thru the M230 Automatic gun with firing voltage disconnected. Ejected rounds were caught in a hammock type container designed to prevent damage to rounds from impact with either the container or other rounds. Burst size was adjusted to minimize the interaction between rounds during the eject (5 and 20 respectively. All test were done at ambient condition.

The test items were visually examined after the debulleting test for loose projectiles and damage to the case. Overall length of each cartridge was measured and recorded. Five (5) test items bullet pulled and the extraction force measured.

RESULTS: There were no debulleting anomalies observed. Slight movement of the projectiles were observed which is considered normal. Post test measurements were:

	AVERAGE	STDEV	MIN	MAX
Cartridge Length	7.815in	0.005	7.805	7.826
Case/Proj Gap	0.017in	0.004	0.010	0.026
Bullet Pull (5)	3142#	119	3050	3350

CONCLUSION: Passed

Test No : 30mm T.W.S.C.C. - Phase I

Description : Debulleting - ADEN
(Ref TD-33 Rev C)

Test Item : 30mm TP Cartridges with Steel Case

Quantity : 125 (25 with inert primers)

Procedure : The test was conducted in the ADEN Automatic gun in belts of 5 cartridges. The last round of each belt was a test item containing an inert primer which chambered but did not fire. The test cartridge was removed from the chamber and set aside for examination. The procedure was repeated until all test units were cycled (chambered). All test were done at ambient temperature.

The test items were visually examined after the debulleting test for loose projectiles and damage to the case. Overall length of each test cartridge was measured and recorded. Five (5) test items were bullet pulled and the extraction force measured.

RESULTS: There were no debulleting anomalies observed related to the ammunition. Gun problems were encountered with the ADEN Auto un used that resulted in 7 damaged cartridges. Post test measurements of the test units successfully cycled were:

	AVERAGE	STDEV	MIN	MAX
Cartridge Length (18)	7.822in	0.021	7.793	7.883
Case/Proj Gap (18)	0.024in	0.016	0.005	0.076
Bullet Pull (5)	3024#	192	2720	3240

CONCLUSION: Passed

TEST GROUP: 30mm T.W.S.C.C. - Phase I

TEST OBJECTIVE: Projectile extraction (TD-14)

TEST ITEM: 30mm T.W.S.C.C.

QUANTITY: 7

PROCEDURE: Projectiles were pulled at a rate of 25mm per minute ± 10%. Test was run on a Baldwin 60K Mod. BTE T.M. SN 512020 Amron fixture No. 4285.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AV. PRESSURE	STD. DEV.
28 Feb. 86	7	13.357 KN	.574 KN		

All projectiles pulled in a normal fashion. The retention force calculated was $\bar{x} - 3a = 10.62$ KN.

All projectiles indicated the presence of waterproof seal. No contamination of propellant was observed.

TEST CONCLUSION: Cartridge Case passed

TABLE 5. 30MM THINWALL STEEL CARTRIDGE CASE

TEST DATA

PHASE 1

TEST	RDS FIRED	TEMP	MUZZLE VELOCITY (M/S) AVG	STD DEV	MIN	MAX	MOUTH PRESSURE (MPa) AVG	STD DEV	MIN	MAX	ACTION TIME (MS) AVG	STD DEV	MIN	MAX
Pressure, Velocity Action Time 230 Mann Barrel	15	21°C	804.6	3.18	783.7	791.8	287.2	4.70	282.7	296.5	2.57	.03	2.54	2.63
	15	21°C	803.6	3.00	781.0	790.3	285.7	5.03	279.2	296.5	1.55	.03	2.50	2.59
	15	21°C	805.5	2.87	781.0	791.5	290.9	7.22	275.8	299.9	2.55	.03	2.54	2.58
	15	71°C	824.6	4.28	800.3	812.5	316.1	8.96	304.1	325.4	2.44	.10	2.37	2.53
	15	-54°C	777.0	3.84	754.4	764.7	265.7	9.89	251.7	286.1	2.85	.08	2.76	3.00
Pressure, Velocity Action Time Waterproofness 230 Mann Barrel	20	21°C	802.5	3.08	782.9	789.4	287.3	6.63	276.5	303.4	2.57	.03	2.54	2.63
Pressure, Velocity Action Time Salt Fog 230 Mann Barrel	20	21°C	805.0	3.06	781.8	791.2	293.0	7.94	281.3	303.4	2.57	.03	2.54	2.61
High Pressure 230 Mann Barrel	20	21°C	N/A	N/A	N/A	N/A	N/A	N/A	406.8	449.6	N/A	N/A	N/A	N/A
Pressure, Velocity Action Time Aden Mann Barrel	10	21°C	801.5	5.9	787.1	806.9	264.8	11.4	239.3	272.2				
	10	71°C	825.1	4.3	800.9	830.1	299.6	11.4	282.0	319.9				
	10	-54°C	785.9	5.1	748.5	765.8	249.9	12.45	233.2	265.65				

TABLE 6. BALLISTIC SUMMARY OF ENVIRONMENTAL TW 30MM STEEL CASE TESTS

ENVIRONMENTAL TEST	TEMP DEG C	MUZZLE VELOCITY (M/S) AVG	SDEV	MIN	MAX	C/MOUTH PRESSURE (MPa) AVG	SDEV	MIN	MAX	ACTION TIME (MS) AVG	SDEV	MIN	MAX
AIRCRAFT VIBRATION	+21	809.9	3.8	803.2	819.9	320.7	9.8	304.1	345.4	2.722	0.120	2.542	3.068
TEMPERATURE HUMIDTY	+21	815.8	3.9	804.2	822.6	351.9	6.4	332.3	360.9	4.073	2.284	2.687	12.803
TRANSPORTATION VIB	+21	809.3	3.4	802.4	813.3	309.1	6.8	296.8	314.7	2.691	0.045	2.634	2.710
	-54	779.4	3.5	772.0	783.8	284.7	5.2	272.7	290.3	3.083	0.140	2.878	3.343
	+71	834.1	4.7	825.7	841.5	348.9	10.2	329.9	364.4	2.561	0.064	2.447	2.677
EXTREME TEMPERATURE	+21	808.7	4.7	795.6	816.2	340.6	6.7	324.5	350.0	2.674	0.085	2.530	2.915
AUTO GUN F & C.	+21	794	6	701	808	NA				NA			
	-54	749	8	736	762	NA				NA			
	+71	810	5	801	823	NA				NA			

X. TEMPERATURE AND HUMIDITY RETEST

To determine the effect and cause of the temperature and humidity discrepancy encountered, a meeting was held at Amron Corporation on May 13, 1986, with the following personnel in attendance:

Ed Kaminski	-	Amron
Mark Sturkol	-	Amron
Dave Bunch	-	Olin, Marion, IL
Paul Bretl	-	Amron
Tom Doris	-	ARDEC, Dover, NJ
Endel Toomsoo	-	ARDEC, Dover, NJ
Debbie Rehm	-	ARDEC, Dover, NJ
Vic Strobush	-	Honeywell, Inc., Minneapolis
Bob Brey	-	Amron
Al Burns	-	Honeywell, Inc., Minneapolis
Gene Weinberger	-	Amron
Keith Rogers	-	Amron
Angelo Cianciosi	-	ARDEC, Dover NJ

Although many possible reasons for the long action times encountered were discussed at the meeting, no conclusion could be reached as to the exact cause.

As a result of the meeting, it was decided to rerun the test devising an expanded test plan.

The plan developed compared temperature and humidity test results of the 30mm thinwall steel case against 30mm light-weight aluminum case supplied by both Olin and Honeywell Corporations. The plan also incorporated the use of both Olin and I.C.I. Corporation's PA 520 primers. The checking of the primer-to-case electrical resistance before, at the half-way point and at the conclusion of the temperature and humidity test was also required.

In addition to the above requirements using 30mm thinwall steel cases, a series of 20mm steel cases were primed with the same primers and subjected to the identical test to compare the resistance in different types of steel cartridge cases using the same primer.

A. Test Program

Due to a limited number of components made available for the test, the following matrix of components comprised the test samples:

DESIGNATION	QUANTITY	DESCRIPTION
A	17	LW 30mm TP cartridge w/Amron aluminum case and ICI PA520 primer
B	17	LW 30mm TP cartridge w/Amron aluminum case and Olin PA520 primer
C	17	LW 30mm TP cartridge w/Piper aluminum case and ICI PA520 primer
D	17	LW 30mm TP cartridge w/Piper aluminum case and Olin PA520 primer
E	17	TW 30mm TP cartridge w/Amron steel case and ICI PA520 primer
F	17	TW 30mm TP cartridge w/Amron steel case and Olin PA520 primer
G	10	20mm TP cartridge w/steel case, ICI PA520 primer and without propellant
H	10	20mm TP cartridge w/steel case, Olin PA520 primer and without propellant

B. Test Results

Attachment 3 is a detailed test report of the information obtained before, during and after the test was completed. In analysis of the data accumulated during the rerun of the test, no conclusive evidence could be determined that indicated the long action times again encountered could be directly attributed to the design of the steel cartridge case. Based on this premise, permission to commence with the Phase II segment of the contract was granted.

XI. BALLISTIC AND ENVIRONMENTAL TEST PROGRAM - PHASE II

A. Phase II - Requirements

The requirement of Phase II was to manufacture 7,200 cartridge cases and subject the manufactured cases to a two-segment test program. The initial test was to assure that the cartridge cases could be accepted on a sample quality level by subjecting a quantity of cartridge cases to a ballistic lot acceptance test.

After cases were accepted as a lot, an expanded qualification test incorporating both ballistic and environmental testing was performed.

B. Lot Acceptance Tests and Results

Table 7 is a tabulation of the number of cartridge cases subjected to the various ballistic tests required for lot acceptance. A description of each of the tests performed and ballistic results achieved at each test follows the tabulation.

When data achieved during testing was analyzed, results of all tests performed were well within the requested requirements.

Based on this information, cases were subjected to the expanded qualification ballistic and environmental test segment of the program.

C. Qualification Tests and Results

Table 8 is a tabulation of the number of cartridge cases subjected to the various ballistic and environmental tests required for qualifying the 30mm thinwall steel case.

Again, a description of each of the tests performed and results achieved follows the tabulation.

Table 15 is a ballistic summary of environmental tests run during the qualification testing of the developed cartridge case.

Table 16 is a ballistic summary of the automatic gun firings conducted when the steel case was loaded with either TP or HEDP projectiles.

TABLE 7

PHASE II TESTING - LOT ACCEPTANCE

SUMMARY

TEST	CONDITION	WEAPON	QUANTITY	ROUND TYPE
Pressure, velocity action time	Ambient	M-230 Mann	50	M-788
Pressure, velocity action time	Hot	M-230 Mann	17	M-788
Pressure, velocity action time	Cold	M-230 Mann	15	M-788
Projectile extraction	Ambient	-	15	M-788
Pressure, velocity action time	Ambient	M-230 Mann	40	M-789
Pressure, velocity action time	Hot	M-230 Mann	10	M-789
Pressure, velocity action time	Cold	M-230 Mann	10	M-789
Function & casualty	Ambient	M-230 Mann	50	M-789
Projectile extraction	Ambient	-	20	M-789

TEST GROUP: 30mm T.W.S.C.C. - L.A.T.

TEST OBJECTIVE: Pressure, Velocity and Action Time TD-01 @ 21° C

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 50

PROCEDURE: Test Groups were fired in an M230 MANN Barrel, at a rate not to exceed three minutes between rounds.

Ammunition was conditioned a minimum of 24 hours @ 21° C before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AVE. PRESSURE	STD. DEV.
27 Jan 87	10 Rds.	814.67 M/S	3.785 M/S	316.40 MPa	9.96 MPa
28 Jan 87	10 Rds.	812.79 M/S	4.344 M/S	308.81 MPa	12.23 MPA
29 Jan 87	30 Rds.	811.24 M/S	4.289 M/S	309.69 MPa	10.58 MPa

There were no case anomalies observed.

Action times recorded resulted in no action times that exceeded four (MS).

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - L.A.T.

TEST OBJECTIVE: Pressure, velocity, and action time (TD-01) @ 71° C

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 17

PROCEDURE: Test group was fired in an M230 MANN Barrel, at a rate not to exceed three minutes between rounds.

Ammunition was conditioned @ 71° C for a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AVE. PRESSURE	STD. DEV.
28 Jan 87	17 Rds.	832.50 M/S	4.255 M/S	338.64 MPa	12.78 MPa

There were no case anomalies observed.

Action times recorded resulted in no action times that exceeded four (MS).

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - L.A.T.

TEST OBJECTIVE: Pressure, velocity and action time TD-01 @ -54° C

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 15

PROCEDURE: Test group was fired in an M230 MANN Barrel, at a rate not to exceed three minutes between rounds.

Ammunition was conditioned @ -54° C for a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AVE. PRESSURE	STD. DEV.
28 Jan 87	15	783.40 M/S	2.20 M/S	272.64 MPa	12.74 MPa

There were no case anomalies observed.

Action times recorded resulted in no action times that exceeded four (MS).

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - L.A.T.

TEST OBJECTIVE: Projectile extraction (TD-14) Presence of water-proof seal, propellant contamination

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 15

PROCEDURE: Projectiles were pulled at a rate of 25mm per minute ± 10%. Test was run on a Baldwin 60k Mod. BTE T.M. SN 512020, Amron fixture No. 4285.

RESULTS:

DATE	QUANTITY	MEAN VALUE	STD. DEV.
28 Jan 87	15	14.004 KN	0.700 KN

All projectiles pulled in a normal fashion. The retention force calculated was $\bar{x} - 3a = 11.904$ Kilo Newtons.

All projectiles indicated the presence of water-proof seal. No contamination of propellant was observed.

TEST CONCLUSION: Cartridge Case passed

TITLE: 30mm T.W.S.C.C. - L.A.T.

SUBJECT: TW30 Steel Cased Ammunition
P.O. 01-63716-RB Item B

MATERIAL LAPPED: 750 TW30mm HEDP Cartridges with Steel Cases
Ammunition Lot # HJA87A425S002

MATERIAL TESTED: 120 TW30mm HEDP Cartridges with Steel Cases
Ammunition Lot # HJA87A425S002

TEST INITIATED: 22 February 1987

TEST COMPLETED: 24 February 1987

TEST CONDUCTED:

Pressure, Velocity, Action Time & Accuracy	- See following sheet
Function & Casualty	- " " "
Projectile Extraction	- " " "

RESULTS: During LAP a high percentage (~10%) of cases were damaged at projectile insertion. To alleviate this problem a chamfer or mouth flare is recommended for the case. No damaged cases were used in the test units. Charge verification tests was not conducted for this lot. Data used was based on a prior steel case build, lot S001. Lot S002 successfully met all LW30mm ballistic requirements.

A...Lot Acceptance Ballistic Data for HEDP Lot HJA87A425S002 w/Steel Case

CHARACTERISTIC	MUZZLE VELOCITY (m/s)	C'MOUTH PRESSURE (MPa)	ACTION TIME (ms)	--ACCURACY-- X-COOR (mils)	Y-COOR
40 @ +21 Deg C					
AVERAGE	805	297.4	2.55	1.78	6.77
STD DEV	9	14.0	0.04	0.42	0.43
MINIMUM	783	266.1	2.49	2.70	5.70
MAXIMUM	833	347.5	2.65	0.66	8.00
10 @ -54 Deg C					
AVERAGE	784	294.8	2.81	1.63	6.56
STD DEV	10	11.9	0.08	0.34	0.53
MINIMUM	767	271.3	2.70	2.00	5.70
MAXIMUM	794	309.6	2.95	1.00	7.60
10 @ +71 Deg C					
AVERAGE	830	342.1	2.32	NA	NA
STD DEV	6	9.5	0.04	0.38	0.54
MINIMUM	817	319.6	2.28	NA	NA
MAXIMUM	837	352.0	2.42	NA	NA

B...Lot Acceptance Function & Casualty for Lot HJA87A425S002

------ BURST ------		--- MUZZLE VELOCITY (m/s) ---		
NO.	RATE (spm)	AVG	MIN	MAX
1	592	798	776	818
2	586	805	774	821

All rounds functioned properly through M230 Auto gun - no breakups observed.

C...Lot Acceptance Bullet Pull for Lot HJA87A425S002

- EXTRACTION FORCE:

AVG	3313 lbs
SD	222
AVG-3S	2647
MIN	2975
MAX	3600

- Lacquer Seal 100 % Present
- No Propellant Contamination

TABLE 8

PHASE II - QUALIFICATION - M788, M789

TEST	CONDITION	GUN	QUANTITY	ROUND TYPE
Pressure, velocity action time	Ambient	M-230 Mann	25	M-788
Pressure, velocity action time	Hot	M-230 Mann	25	M-788
Pressure, velocity action time	Cold	M-230 Mann	26	M-788
Water proofness	Ambient	M-230 Mann	10	M-788
Water proofness	Hot	M-230 Mann	10	M-788
Water proofness	Cold	M-230 Mann	10	M-788
Salt fog	Ambient	M-230 Mann	20	M-788
Overpressure	Ambient	M-230 Mann	25	M-788
Pressure, velocity action time	Ambient	Aden Mann	10	M-788
Pressure, velocity action time	Hot	Aden Mann	10	M-788
Pressure, velocity action time	Cold	Aden Mann	10	M-788
Projectile extraction	Ambient	-	20	M-788
Water proofness inspection	Ambient	-	5	M-788
Salt fog inspection	Ambient	-	5	M-788
Aircraft vibration	Ambient	M-230	25	M-788
Temperature-humidity	Ambient	M-230 Mann	35	M-788
Extreme temperature	Ambient	M-230 Mann	35	M-788
Transportation vibration	Ambient	M-230 Mann	35	M-788
Rough handling	Ambient	M-230 Mann	25	M-788
Thermal shock	Ambient	M-230 Mann	25	M-788
Function & casualty weapon compatibility	Ambient	M-230 Auto	200	M-788

PHASE II - QUALIFICATION - M788, M789

TEST	CONDITION	GUN	QUANTITY	ROUND TYPE
Function & casualty weapon compatibility	Hot	M-230 Auto	200	M-788
Function & casualty weapon compatibility	Cold	M-230 Auto	200	M-788
Function & casualty weapon compatibility	Ambient	M-230 Auto	200	M-789
Function & casualty weapon compatibility	Hot	M-230 Auto	200	M-789
Function & casualty weapon compatibility	Cold	M-230 Auto	200	M-789
Debulleting	Ambient	M-230 Auto	25	M-788
Debulleting	Ambient	Aden Auto	125	M-788

TEST GROUP: 30mm T.W.S.C.C. - Qual.

TEST OBJECTIVE: Pressure, velocity and action time (TD-01) @ 21° C

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 25

PROCEDURE: Test group was fired in an M230 MANN Barrel, at a rate not to exceed three minutes between rounds.

Ammunition was conditioned @ 21° C for a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AVE. PRESSURE	STD. DEV.
18 Feb 87	25 Rds.	807.06 M/S	4.54 M/S	298.14 MPa	10.79 MPa

There were no case anomalies observed.

Action times recorded resulted in no action times that exceeded four (MS).

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Qual.

TEST OBJECTIVE: Pressure, velocity and action time (TD-01) @ 71°C

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 25

PROCEDURE: Test group was fired in an M230 MANN Barrel at a rate not to exceed three minutes between rounds.

Ammuntion was conditioned @ 71° C for a minimum of 24 hrs. before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AVE. PRESSURE	STD. DEV.
19 Feb 87	25	830.70 M/S	3.10 M/S	336.37 MPa	9.13 MPa

There were no case anomalies observed.

Action times recorded resulted in no action times that exceeded four (MS).

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Qual.

TEST OBJECTIVE: Pressure, velocity and action time (TD-01) @ -54° C

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 26

PROCEDURE: Test group was fired in an M230 MANN Barrel, at a rate not to exceed three minutes between rounds.

Ammunition was conditioned @ -54° C for a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AVE. PRESSURE	STD. DEV.
19 Feb 87	26 Rds.	780.10 M/S	2.30 M/S	275.47 MPa	7.34 MPa

There were no case anomalies observed.

Action times recorded resulted in no action times that exceeded four (MS) and one action time was below two (MS) which was related to a wiring problem at the MANN Barrel.

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Qual.

TEST OBJECTIVE: Pressure, velocity and action time waterproofness (TD-18) @ 21° C.

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 10

PROCEDURE: Test group was fired in an M230 MANN Barrel, at a rate not to exceed three minutes between rounds.

Ammunition was conditioned for waterproofness per (TD-18) and conditioned @ 21° C for a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AVE. PRESSURE	STD. DEV.
20 Feb 87	10	807.7 M/S	4.78 M/S	298.35 MPa	11.85 MPa

There were no case anomalies observed.

Action times recorded resulted in no action times that exceeded four (MS).

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Qual.

TEST OBJECTIVE: Pressure, velocity and action time waterproofness (TD-18) @ 71° C

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 10

PROCEDURE: Test group was fired in an M230 MANN Barrel, at a rate not to exceed three minutes between rounds.

Ammunition was conditioned for waterproofness per (TD-18) and conditioned @ 71° C for a minimum of 24 hours and conditioned @ 21° C for a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AVE. PRESSURE	STD. DEV.
20 Feb 87	11 Rds.	814.80 M/S	3.48 M/S	317.10 MPa	8.56 MPa

There were no case anomalies observed.

Action times recorded resulted in no action times that exceeded four (MS).

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Qual.

TEST OBJECTIVE: Pressure, velocity and action time waterproofness (TD-18) @ -54° C

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 10

PROCEDURE: Test group was fired in an M230 MANN Barrel, at a rate not to exceed three minutes between rounds.

Ammunition was conditioned for waterproofness per (TD-18) and conditioned @ -54° C for a minimum of 24 hrs. and conditioned @ 21° C for a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AVE. PRESSURE	STD. DEV.
20 Feb 87	10	803.40 M/S	5.38 M/S	292.27 MPa	11.76 MPa

There were no case anomalies observed.

Action times recorded resulted in no action times that exceeded four (MS)

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Qual.

TEST OBJECTIVE: Pressure, velocity and action time
Salt Fog (Spray) (TD-19) @ 21° C

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 20

PROCEDURE: Test group was fired in an M230 MANN Barrel, at a rate not to exceed three minutes between Rounds.

Ammunition was conditioned per (TD-19) Salt Fog for 48 hours and conditioned @ 21° C for a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AVE. PRESSURE	STD. DEV.
23 Feb 87	20	810.60 M/S	3.98 M/S	304.59 MPa	9.43 MPa

There were no case anomalies observed.

Action times recorded resulted in no action times that exceeded four (MS).

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Qual.

TEST OBJECTIVE: Pressure, velocity and action time
Overpressure @ 21° C 55.0 gram charge

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 25

PROCEDURE: Test group was fired in an M230 MANN Barrel, at a rate not to exceed three minutes between rounds.

Ammunition was conditioned @ 21° C for a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AVE. PRESSURE	STD. DEV.
24 Feb 87	25 Rds.	879.90 M/S	6.88 M/S	432.26 MPa	10.62 MPa

There were no case anomalies observed.

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Qual.

TEST OBJECTIVE: Pressure, velocity and action time
Aden MANN Barrel @ 21° C

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 10

PROCEDURE: Test group was fired in an Aden MANN Barrel, at a rate not to exceed three minutes between rounds.

Ammunition was conditioned @ 21° C, a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AVE. PRESSURE	STD. DEV.
27 Feb 87	10 Rds.	805.30 M/S	2.80 M/S	266.15 MPa	6.21 MPa

There were no case anomalies observed.

Action times recorded resulted in no times that exceeded four (MS)

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Qual.

TEST OBJECTIVE: Pressure, velocity and action time
Aden MANN Barrel @ 71° C

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 10

PROCEDURE: Test group was fired in an Aden MANN Barrel, at a rate not to exceed three minutes between rounds.

Ammunition was conditioned @ 71° C for a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AVE. PRESSURE	STD. DEV.
27 Feb 87	10 Rds.	824.10 M/S	3.00 M/S	293.73 MPa	9.65 MPa

There were no case anomalies observed.

Action time recorded resulted in no action times that exceeded four (MS)

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Qual.

TEST OBJECTIVE: Pressure, velocity and action time Aden MANN Barrel @-54° C

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 10

PROCEDURE: Test group was fired in an Aden MANN Barrel at a rate not to exceed three minutes between rounds.

Ammunition was conditioned @ -54° C for a minimum of 24 hours before firing.

RESULTS:

DATE	QUANTITY	V-MUZZLE	STD. DEV.	AVE. PRESSURE	STD. DEV.
27 Feb 87	10 Rds.	766.30 M/S	10.30 M/S	248.91 MPa	7.58 MPa

There were no case anomalies observed.

Action times recorded resulted in no action times that exceeded four (MS).

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Qual.

TEST OBJECTIVE: Projectile extraction (TD-14)

TEST ITEM: 30mmThinwall Steel Cartridge Case

QUANTITY: 20

PROCEDURE: Projectiles were pulled at a rate of 25mm per minute ± 10%. Test was run on a Baldwin 60K Mod. BTE T.M. SN 512020 Amron fixture No. 4285.

RESULTS:

DATE	QUANTITY	MEAN VALUE	STD. DEV.
20 Feb 87	20	14.634 KN	1.339 KN

All projectiles pulled in a normal fashion. The retention force calculated was $x - 3a = 10.62$ KN.

All projectiles indicated the presence of waterproof seal. No contamination of propellant was observed.

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Qual.

TEST OBJECTIVE: Waterproofness (TD-18) @ 21° C
Disassembly and inspect for propellant and case contamination.

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 5

PROCEDURE: Ammunition was conditioned for waterproofness per (TD-18) and conditioned @ 21° C for a minimum of 24 hours.

Projectiles were poulled on a Baldwin 60K Mod. BTE T.M. SN 51202, Amron fixture No. 4285.

RESULTS:

DATE

27 Feb 87

All projectiles indicated the presence of waterproof seal. No contamination of propellant was observed. The case interior showed no signs of leakage at the projectile or primer areas of the subject cases.

TEST CONCLUSION: Cartridge Case passed

TEST GROUP: 30mm T.W.S.C.C. - Qual.

TEST OBJECTIVE: Salt Fog (Spray)(TD-19) @ 21° C
Disassembly and inspect for propellant and case contamination

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 5

PROCEDURE: Ammunition was conditioned per (TD-19) Salt Fog for 48 hours and conditioned @ 21° C for a minimum of 24 hours.

Projectiles were pulled on a Baldwin 60K Mod. BTE T.M. SN 51202, Amron fixture No. 4285.

RESULTS:

DATE	
27 Feb 87	All projectiles indicated the presence of waterproof seal. No contamination of propellant was observed. The case interior showed no signs of leakage at the projectile or primer areas of the subject cases.

TEST CONCLUSION: Cartridge Case passed

TEST NO: TW30-SC4 - Group A

DESCRIPTION: Aircraft Vibration per MIL-STD-810C, Method 514.2 (Ref TD-30 Rev E)

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 25

PROCEDURE: Cartridges were tested in the M592 Ammunition container. The test items were linked and randomly distributed about the container. The balance of the container was filled with linked non-test TP cartridges (72 full container) to achieve normal pack tightness and weight. The loaded container was attached rigidly to the vibration fixture. Vibration testing was conducted in accordance with Procedure I, Category C, reference Table 514.2-III and Figure 514.2-3. Each test item was vibrated for 3 hours/axis (3) at -54C and +71C (18 hours total). Pre-conditioning time at each temperature was 8 hours minimum. All test items were examined visually after the vibration exposure and any anomaly related to the steel case such as loose primers, loose projectiles, scratches, dents, etc. was noted. All test items were then subjected to ballistic tests in the M230 Mann Barrel wherein velocity, pressure, action time and MPS were measured.

RESULTS: Each round showed minor wear (scratches) where the round was linked. This is a normal occurrence with linked ammunition. Ballistic data indicated no adverse A/V effects except for one (1) round which exhibited an excessive action time. This is considered a non-case related anomaly. The ballistic data is detailed in Table 9, and a comparison with other environments is summarized in Table 15 .

CONCLUSION: Passed

TABLE 9

BALLISTIC RESULTS - AIRCRAFT VIBRATION TEST

S/N GROUP A	MUZZLE VELOCITY (m/s)	CASEMOUTH PRESSURE (psi)	ACTION TIME (ms)	PRIMER RESISTANCE (ohms) PRE TEST	POST TEST	PRIOR FIRING
1	802.4	43650	2.824	NA	NA	NA
2	812.1	45800	3.200	NA	NA	NA
3	805.3	44100	4.364	NA	NA	NA
4	NA	43150	2.740	NA	NA	NA
5	802.8	NA	2.776	NA	NA	NA
6	NA	43250	3.232	NA	NA	NA
7	NA	43250	2.795	NA	NA	NA
8	NA	41550	2.864	NA	NA	NA
9	NA	42950	2.713	NA	NA	NA
10	818.7	45300	2.921	NA	NA	NA
11	NA	NA	3.668	NA	NA	NA
12	NA	45700	2.850	NA	NA	NA
13	800.0	42500	2.923	NA	NA	NA
14	795.1	41050	2.670	NA	NA	NA
15	809.4	44300	2.750	NA	NA	NA
16	809.7	NA	3.518	NA	NA	NA
17	815.1	45900	2.709	NA	NA	NA
18	802.9	43250	2.887	NA	NA	NA
19	813.0	45600	2.632	NA	NA	NA
20	809.4	43600	2.788	NA	NA	NA
21	812.6	44300	3.326	NA	NA	NA
22	807.4	43500	2.835	NA	NA	NA
23	814.9	NA	2.662	NA	NA	NA
24	803.6	42850	2.653	NA	NA	NA
25	809.8	45100	2.819	NA	NA	NA
AVERAGE	808.0	43840	2.965			
STD DEV	6.1	1363	0.399			
MINIMUM	795.1	41050	2.632			
MAXIMUM	818.7	45900	4.364			

TEST NO: TW30-SC4 - Group B

DESCRIPTION: Temperature-Humidity per MIL-STD-331A, Test 105.1 (Ref TD-20 Rev E)

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 35

PROCEDURE: Cartridges were placed in the temperature humidity chamber horizontally on a chrome plated rack. The 28 day (2 cycle) test, as described in test 105.1, was conducted. All test items were examined visually after 14 days (1 cycle) and after 28 days and any corrosive anomaly noted including photographic documentation. Five (5) test items were disassembled after the test and visually examined for evidence of internal moisture or corrosion. The remaining 30 test items were subjected to ballistic test in the M230 Mann barrel wherein velocity, pressure, action time and MPS were measured.

RESULTS: External examination indicated only slight corrosive residue at the primer and projectile interfaces, none was considered significant. Teardown of the 5 units showed slight propellant sticking on inside case wall but no evidence of moisture. The expended units were returned to AMRON without further analysis. Primer resistance measured as a requirement of this this test showed several exceeded the 1000 ohm requirement. Range from 398 to >10,000 ohms. Ballistically the rounds had normal pressure and velocity for post T&H firings, but many (17) had action times in excess of the 4 milliseconds requirement. One round failed to fire and was returned to AMRON. The ballistic data is detailed in Table 10 and a comparison with other environments is summarized in Table 15.

CONCLUSION: Cartridge Failed due to action times greater than 4 milliseconds. From a case standpoint however, results were acceptable.

TABLE 10

BALLISTIC RESULTS - TEMPERATURE HUMDITY TEST

S/N GROUP B	MUZZLE VELOCITY (m/s)	CASEMOUTH PRESSURE (psi)	ACTION TIME (ms)	PRIMER RESISTANCE (ohms) PRE TEST	POST TEST	PRIOR FIRING
1 (26)	815.3	NA	6.529	210	460	445
2	TEARDOWN UNIT			230	590	NA
3	818.9	47850	5.891	560	410	398
4	815.0	47400	3.084	290	350	NA
5	821.7	49300	3.242	260	620	610
6	TEARDOWN UNIT			250	770	NA
7	814.1	46600	2.690	440	890	609
8	813.7	48150	5.617	330	870	860
9	819.6	49450	5.357	270	880	882
10	822.2	49600	5.230	410	950	478
11	811.7	47100	4.038	310	760	753
12	817.3	48600	2.937	280	1340	1210
13	813.9	48200	2.856	320	610	588
14	821.6	50200	5.859	250	920	915
15	813.9	48300	7.042	230	650	640
16	813.9	NA	9.507	230	500	550
17	808.0	44550	2.891	290	3440	2200
18	TEARDOWN UNIT			230	840	NA
19	817.2	48800	3.110	320	1390	2060
20	812.8	47900	3.233	460	1120	808
21	813.2	48350	4.160	210	860	940
22	TEARDOWN UNIT			300	840	NA
23	814.6	48050	3.166	260	1040	1030
24	817.1	47700	2.751	260	410	340
25	--- NO FIRE ---			1800	10330	9400
26	815.4	48500	4.860	380	1110	892
27	TEARDOWN UNIT			320	900	NA
28	814.8	47250	5.522	350	740	735
29	813.2	48800	9.318	280	1010	1100
30	815.1	48850	4.884	280	480	400
31	820.7	48550	3.722	300	450	470
32	815.7	46150	4.692	750	1110	715
33	819.8	48200	4.073	360	1050	1025
34	813.1	46350	7.179	500	880	880
35 (60)	812.2	47550	2.839	280	820	820
AVERAGE	815.7	48011	4.699	366	1154	1129
STD DEV	3.4	1185	1.884	273	1677	1646
MINIMUM	808.0	44550	2.690	210	350	340
MAXIMUM	822.2	50200	9.507	1800	10330	9400

TEST NO: TW30-SC4 - Group C

DESCRIPTION: Extreme Temperature Storage per MIL-STD-331A, Test 112.1 (Ref TD-24 Rev D)

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 35

PROCEDURE: Cartridges were placed in the temperature chamber horizontally. The 56 day storage test, as described in test 112.1 Procedure I, was conducted. All test items were examined visually and any corrosive or temperature anomaly effects noted. Five (5) test items were disassembled and components visually examined for anomalies. The remaining 30 test items were subjected to ballistic test in the M230 Mann barrel wherein velocity, pressure, action time and MPS were measured.

RESULTS: There were no ETS related or ballistic anomalies observed. Teardown of 5 units showed a slight amount of propellant stuck to the inside case wall but propellant not stuck was loose and flowed freely. Resistance of all 35 units were checked after the storage test and found to be normal (range from 60 to 550 ohms). The ballistic data is detailed in Table II and a comparison with other environments is summarized in Table 15.

CONCLUSION: Passed

TABLE 11

BALLISTIC RESULTS - EXTREME TEMPERATURE STORAGE TEST

S/N GROUP C	MUZZLE VELOCITY (m/s)	CASEMOUTH PRESSURE (psi)	ACTION TIME (ms)	PRIMER RESISTANCE (ohms) PRE TEST	POST TEST	PRIOR FIRING
1 (61)	809.4	49000	2.848	370	190	210
2	809.4	49450	2.656	280	180	190
3	802.2	46600	2.649	220	70	74
4	805.5	49550	2.849	270	370	371
5	809.0	49700	2.722	380	60	67
6	802.6	47100	2.537	310	200	206
7	801.3	48500	2.715	230	270	314
8	804.8	49750	2.661	330	130	181
9	806.1	50550	NA	270	270	276
10	811.6	52100	2.773	320	240	234
11	802.8	48250	4.441	500	160	159
12	804.2	49350	2.930	250	190	185
13	802.0	46800	2.676	270	210	215
14	807.7	49350	3.045	260	130	132
15	804.3	47300	2.855	240	150	154
16	801.8	47850	2.687	340	80	95
17	TEARDOWN UNIT			430	310	NA
18	810.8	50500	NA	350	230	236
19	TEARDOWN UNIT			280	160	NA
20	TEARDOWN UNIT			220	150	NA
21	TEARDOWN UNIT			270	510	NA
22	809.9	50950	2.731	270	350	346
23	810.2	49850	NA	260	120	108
24	808.4	49300	2.389	280	400	342
25	802.3	NA	2.788	240	550	313
26	TEARDOWN UNIT			290	150	NA
27	806.2	NA	2.899	380	240	244
28	809.2	NA	2.740	350	250	252
29	806.4	50250	2.242	270	260	249
30	798.5	48400	2.804	220	340	342
31	803.8	50700	2.768	260	110	116
32	802.2	51400	2.568	290	370	374
33	802.8	48200	2.614	400	200	195
34	797.0	49100	2.967	340	340	341
35 (95)	805.6	50000	5.667	440	520	497
AVERAGE	805.3	49254	2.897	305	242	234
STD DEV	3.7	1392	0.666	68	126	103
MINIMUM	797.0	46600	2.242	220	60	67
MAXIMUM	811.6	52100	5.667	500	550	497

TEST NO: TW30-SC4 - Group D

DESCRIPTION: Transportation Vibration-Temperature per MIL-STD-331A, Test 119 (Ref TD-12 Rev E)

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 35

PROCEDURE: Cartridges were tested in the M592 Ammunition container. The test items were linked and randomly distributed about the container. The balance of the container was filled with linked non-test TP cartridges (72 full container) to achieve normal pack tightness and weight. The loaded container was attached rigidly to the vibration fixture. Vibration testing was then conducted as described in test 119, Procedure 1. Twelve (12) test units each were tested at -54C and +71C and eleven (11) tested at +21C. In addition, the -54C and +71C had been previously tested at +71C (inadvertently) prior to there respective

temperature. All test items were examined visually after the vibration exposure and any anomaly related to the steel case such as loose primers, loose projectiles, scratches, dents, etc. were noted. Five (5) test items were set aside for disassembly. The remaining 30 test items were subjected to ballistic tests in the M230 Mann barrel at the same temperature that vibration occurred wherein velocity, pressure, action time and MPS were measured.

RESULTS: Each round showed minor wear (scratches) where the round was linked. This is a normal occurence with linked ammunition. Ballistic data indicated no adverse TVT effects. The ballistic data is detailed in Table 12 and comparison with other environments is summarized in Table 15.

CONCLUSION: Passed

TABLE 12

BALLISTIC RESULTS - TRANSPORTATION VIBRATION TEST

S/N GROUP D	MUZZLE VELOCITY (m/s)	CASEMOUTH PRESSURE (psi)	ACTION TIME (ms)	PRIMER RESISTANCE (ohms) PRE TEST	POST TEST	PRIOR FIRING
98 (AMB)	815.2	45800	2.782	NA	NA	NA
99	808.3	NA	2.729	NA	NA	NA
103	808.9	42550	2.940	NA	NA	NA
106	801.5	41400	2.778	NA	NA	NA
109	805.9	41900	2.686	NA	NA	NA
111	814.4	44850	2.663	NA	NA	NA
126	804.6	42750	2.645	NA	NA	NA
123	811.0	43650	2.673	NA	NA	NA
123	813.4	44750	2.714	NA	NA	NA
119	815.6	47150	2.516	NA	NA	NA
AVERAGE	809.9	43867	2.713			
STD DEV	4.9	1912	0.110			
96 (HOT)	829.1	48250	2.592	NA	NA	NA
97	838.5	50400	2.478	NA	NA	NA
100	842.1	51950	2.520	NA	NA	NA
104	838.2	50600	2.413	NA	NA	NA
105	836.1	48450	2.518	NA	NA	NA
107	837.9	50500	2.413	NA	NA	NA
108	839.9	51250	2.462	NA	NA	NA
110	835.3	48900	2.661	NA	NA	NA
112	840.6	51900	2.448	NA	NA	NA
115	837.7	49750	2.426	NA	NA	NA
AVERAGE	837.5	50195	2.493			
STD DEV	3.6	1338	0.082			
113 COLD	779.0	40450	3.154	NA	NA	NA
118	773.7	39500	2.846	NA	NA	NA
120	776.4	38400	2.923	NA	NA	NA
121	776.5	37900	3.227	NA	NA	NA
122	777.5	38400	3.095	NA	NA	NA
124	773.2	38000	2.914	NA	NA	NA
125	785.7	40900	3.279	NA	NA	NA
127	784.2	41000	3.242	NA	NA	NA
128	779.1	41115	3.450	NA	NA	NA
129	777.1	40700	3.208	NA	NA	NA
AVERAGE	778.2	39637	3.134			
STD DEV	4.0	1342	0.190			

TEARDOWN UNITS #101, 102, 114, 116, 117

TEST NO: TW30-SC4 - Group E

DESCRIPTION: Rough Handling per MIL-STD-331A, Test 114 (Ref TD-11 Rev E)

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 25

PROCEDURE: Cartridges were tested in the M592 Ammunition container. The test items were linked and randomly distributed about the container. The balance of the container was filled with linked non-test TP cartridges (72 full container) to achieve normal pack tightness and weight. The loaded container was attached rigidly to the vibration fixture. Rough handling testing was conducted in accordance with test 114 and at ambient temperature. All test items were examined visually after the rough handling exposure and any anomaly related to the steel case such as loose primers, loose projectiles, scratches, dents, etc. was noted. All test items were then subjected to ballistic tests in the M230 Mann barrel wherein velocity, pressure, action time and MPS were measured.

RESULTS: Only minor scratches occurred where the round was linked. This is a normal occurence with linked ammunition. Ballistic data indicated no adverse RH effects. The ballistic data is detailed in Table 13 and comparison with other environments is summarized in Table 15.

CONCLUSION: Passed.

TABLE 13

BALLISTIC RESULTS - ROUGH HANDLING TEST

S/N GROUP E	MUZZLE VELOCITY (m/s)	CASEMOUTH PRESSURE (psi)	ACTION TIME (ms)	PRIMER RESISTANCE (ohms) PRE TEST	POST TEST	PRIOR FIRING
1 (132)	808.4	42950	2.661	NA	NA	NA
2	816.1	45950	2.661	NA	NA	NA
3	807.8	43050	2.783	NA	NA	NA
4	808.3	42700	2.709	NA	NA	NA
5	804.7	42200	2.726	NA	NA	NA
6	806.1	42500	3.021	NA	NA	NA
7	809.1	42150	2.755	NA	NA	NA
8	804.9	41500	2.810	NA	NA	NA
9	804.1	40050	2.781	NA	NA	NA
10	803.5	40550	2.785	NA	NA	NA
11	804.6	41300	2.852	NA	NA	NA
12	818.9	45450	2.855	NA	NA	NA
13	805.0	41950	2.835	NA	NA	NA
14	804.8	41450	2.763	NA	NA	NA
15	820.9	46850	2.721	NA	NA	NA
16	816.0	45100	2.631	NA	NA	NA
17	815.7	44950	2.844	NA	NA	NA
18	811.0	43000	2.712	NA	NA	NA
19	813.5	42550	2.616	NA	NA	NA
20	800.1	39250	2.682	NA	NA	NA
21	812.9	42600	2.778	NA	NA	NA
22	814.8	43450	3.076	NA	NA	NA
23	811.9	43350	2.829	NA	NA	NA
24	814.1	44900	2.778	NA	NA	NA
25 (155)	807.5	42550	2.527	NA	NA	NA
AVERAGE	809.8	42892	2.768			
STD DEV	5.4	1838	0.117			
MINIMUM	800.1	39250	2.527			
MAXIMUM	820.9	46850	3.076			

TEST NO: TW30-SC4 - Group F

DESCRIPTION: Thermal Shock per MIL-STD-331A, Test 113.1 (Ref TD-23 Rev E)

TEST ITEM: 30mm Thinwall Steel Cartridge Case

QUANTITY: 25

PROCEDURE: Cartridges were placed in the temperature chamber horizontally. The thermal shock test, as described in test 113.1, was conducted. All test items had primer resistance measured before the test, after the test and prior to firing. All test items were examined visually after the test and any anomaly related to the steel case was noted. All test items were subjected to ballistic test in the M230 Mann barrel wherein velocity pressure, action time and MPS were measured.

RESULTS: There were no TS related or ballistic anomalies observed. Primer resistance checked after thermal shock was normal (range 50 to 90 ohms) but significantly lower than before the test. Ballistic data is detailed in Table 14 and comparison with other environments is summarized in Table 15.

CONCLUSION: Passed.

TABLE 14

BALLISTIC RESULTS - THERMAL SHOCK TEST

S/N GROUP F	MUZZLE VELOCITY (m/s)	CASEMOUTH PRESSURE (psi)	ACTION TIME (ms)	PRIMER RESISTANCE (ohms) PRE TEST	POST TEST	PRIOR FIRING
1 (156)	814.6	44500	2.783	220	80	95
2	808.0	42900	2.828	300	60	68
3	803.2	40800	2.853	280	80	82
4	803.9	40000	2.644	200	50	57
5	803.1	40900	2.818	270	60	72
6	819.6	45550	2.748	340	90	105
7	797.2	40550	2.663	240	80	85
8	802.9	41100	2.674	220	50	54
9	804.6	41300	2.939	360	70	80
10	813.1	43700	2.708	320	80	88
11	814.0	45400	2.780	270	60	70
12	816.5	45950	2.906	290	90	99
13	806.8	42000	2.802	230	70	81
14	807.3	41100	2.810	210	60	63
15	812.6	43750	2.821	220	50	59
16	817.1	45950	2.829	250	60	69
17	812.5	44100	NA	280	70	89
18	810.0	43450	3.011	320	60	76
19	804.1	41700	2.887	250	70	77
20	805.5	42350	2.701	240	80	55
21	806.5	42650	2.780	270	60	77
22	818.5	46300	2.879	220	70	80
23	798.6	39550	2.751	280	70	63
24	811.4	42750	2.750	260	60	73
25 (180)	818.3	44750	2.814	250	70	77
AVERAGE	809.2	42922	2.799	264	68	76
STD DEV	6.3	2018	0.089	42	12	13
MINIMUM	797.2	39550	2.644	200	50	54
MAXIMUM	819.6	46300	3.011	360	90	105

TEST NO : T.W30-SC5 - Group A & B

DESCRIPTION : Function & Casualty/Weapon Compatibility

(Ref TD-38 Rev C / TD-41 Rev F)

TEST ITEM : 30mm Thinwall Steel Cartridge Case
.W30mm HEDP Cartridges with Steel Case

QUANTITY : 600 TP
600 HEDP

PROCEDURE : The test items were fired in the M230 Automatic Gun as follows:

Quantity TP	Quantity HEDP	Ammo Temp	Burst Size
200	200	+21 C	25
200	200	-54 C	25
200	200	+71 C	25

Ammunition conditioning prior to firing was 2 hours minimum.

The following data was recorded:

...Muzzle velocity, burst rate, cooling time
...Metal parts security
...Anomalies in performance of ammo or weapon
...Case related anomalies such as primer leaks, loose primers, split cases, extractor tears, etc.

RESULTS: One case split longitudinally (~3.5 inches) during +71C testing with TP ammunition. It had no effect on safety or gun operation since it obturated properly and all gases were confined within the barrel. The case anomaly was returned to AMRON for analysis. The steel case has no effect on M230 Auto gun cyclic rate.

o Average Steel Case Rate (48 Bursts) = 588.5 spm
o Average Alum Case Rate (28 Bursts) = 588.9 spm

CONCLUSION: Passed

TEST NO : TW30-SC5 - Group C

DESCRIPTION : Debulleting - M230
(Ref TD-33 Rev C)

TEST ITEM : 30mm Thinwall Steel Cartridge Case

QUANTITY : 25

PROCEDURE : The test items were cycled thru the M230 Autcmatic gun with firing voltage disconnected. Ejected rounds were caught in a hammock type container designed to prevent damage to rounds from impact with either the container or other rounds. Burst size was 25. All tests were done at ambient condition. The test items were visually examined after the debulleting test for loose projectiles and damage to the case. Overall length of each cartridge was measured and recorded. Five (5) test items bullet pulled and the extraction force measured.

RESULTS: There were no debulleting anomalies observed. No movement of the projectiles were observed as a result of the debulleting action. Post test measurements were:

	AVERAGE	STDEV	MIN	MAX
Cartridge Length	7.820in	0.007	7.807	7.835
Bullet Pull (5)	3412#	97	3270	3540

CONCLUSION: Passed

TEST NO : T.W30-SC5 - Group D

DESCRIPTION : Debulleting - ADEN
(Ref TD-33 Rev C)

TEST ITEM : 30mm Thinwall Steel Cartridge Case

QUANTITY : 125 (25 with inert primers)

PROCEDURE : The test was conducted in the ADEN Automatic gun in belts of 5 cartridges. The last round of each belt was a test item containing an inert primer which chambered but did not fire. The test cartridge was removed from the chamber and set aside for examination. The procedure was repeated until all test units were cycled (chambered). All test were done at ambient temperature. The test items were visually examined after the debulleting test for loose projectiles and damage to the case. Overall length of each test cartridge was measured and recorded. Five (5) test items were bullet pulled and the extraction force measured.

RESULTS: There were no debulleting anomalies observed. Slight projectile movement was observed on two (2) units. Post test measurements were:

	AVERAGE	STDEV	MIN	MAX
Cartridge Length	7.822in	0.006	7.814	7.835
Bullet Pull (5)	3156#	408	2490 *	3590

* Includes 1 of 2 with loose projectile

CONCLUSION: Passed

TABLE 15

BALLISTIC SUMMARY OF ENVIRONMENTAL TW30MM STEEL CASE QUALIFICATION TESTS

ENVIRONMENTAL TEST	TEMP DEG C	MUZZLE VELOCITY (M/S) AVG	SDEV	MIN	MAX	C/MOUTH PRESSURE (PSI) AVG	SDEV	MIN	MAX	ACTION TIME (MS) AVG	SDEV	MIN	MAX
AIRCRAFT VIBRATION	+21	808.0	6.1	795.1	818.7	43840	1363	41050	45900	2.965	0.399	2.632	4.364
TEMPERATURE HUMIDITY	+21	815.7	3.4	808.8	822.2	48011	1185	44550	50200	4.699	1.884	2.690	9.507
EXTREME TEMPERATURE	+21	805.3	3.7	797.0	811.6	49254	1392	46600	52100	2.897	0.666	2.242	5.667
TRANSPORTATION VIB	+21	809.9	4.9	801.5	815.6	43867	1912	41400	47150	2.713	0.110	2.516	2.940
	+71	837.5	3.6	829.1	842.1	50195	1338	48250	51950	2.493	0.082	2.413	2.661
	-54	778.2	4.0	773.2	785.7	39637	1342	37900	41115	3.134	0.190	2.846	3.458
ROUGH HANDLING	+21	809.8	5.4	800.1	820.9	42892	1838	39250	46850	2.768	0.117	2.527	3.076
THERMAL SHOCK	+21	809.2	6.3	797.2	819.6	42922	2118	39550	46300	2.799	0.089	2.644	3.011

TABLE 16

BALLISTIC SUMMARY OF FUNCTION & CASUALTY TW30MM STEEL CASE QUALIFICATION TESTS

AMMO	TEMP Deg C	NUMBER BURST	CYCLIC RATE BURST AVG	CYCLIC RATE BURST RANGE	VELOCITY (m/s) BURST AVG	VELOCITY (m/s) BURST SDEV	VELOCITY (m/s) INDIV MIN	VELOCITY (m/s) INDIV MAX
TP	+21	8	587	24	788.3	1.4	775	799
HEDP	+21	3	580	12	790.6	3.5	755	803
TP	-54	8	591	10	754.1	2.4	736	777
HEDP	-54	8	587	10	763.8	4.3	728	789
TP (1)	+71	8	592	11	816.7	2.5	802	830
HEDP	+71	8	586	15	815.3	4.1	796	831

(1) Split case occurred in burst #6

XII. FINAL CONCLUSIONS

When all the data was analyzed from the numerous ballistic and environmental tests the 30mm thinwall steel cartridge case was subjected to was analyzed, no anomalies could be detected that would be a detriment to the design of the cartridge case.

In final analysis, a 30mm steel cartridge case suitable for use in either the M230 chain or ADEN revolver gun has been demonstrated.

The case is manufactured from 10B22 steel; then heat treated to various hardnesses in the case configuration.

Finished case is coated with a protective coating of Northern LX-1060 lacquer applied over a zinc plate and chromate base.

Weight of the finished case is 113.5 grams. The internal volume has been measured at 71.4 cc.

During the manufacture of the 7,200 piece quantity required for Phase II, the manufacturing process and tooling used to manufacture the cases was demonstrated under mass production type conditions.

In view of the excellent results achieved, a case specification has been written and is in the final stage of revision and acceptance by ARDEC personnel.

APPENDIX A

PURCHASE SPECIFICATION 10B22 STEEL

AMRON CORPORATION
Waukesha, Wisconsin

PURCHASE SPECIFICATION

REV A
17 August 1989

PS-1076-30mm Thinwall Steel

Hot Rolled Carbon Steel For Cartridge Case, 30mm Thinwall Steel

I. SCOPE

This purchase specification supplements the applicable ASTM specifications in establishing the requirements which must be met by producers supplying Amron Corporation with boron treated hot rolled cold extrusion quality B carbon steel bar for the manufacture of the 30mm thinwall steel cartridge case.

II. APPLICABLE DOCUMENTS

Hot rolled carbon steel bar provided under this purchase specification shall be produced in full accordance with the following specifications.

ASTM A576	Special Quality Hot Rolled Carbon Steel Bars.
ASTM A29	Steel Bar, Carbon and Alloy, Hot Rolled and Cold Finished, General Requirements for.

III. REQUIREMENTS

A. Type of Steel

Steel provided to this purchase specification shall be aluminum killed fine grain cold extrusion quality B hot rolled steel bar. The steel is to be used by Amron to manufacture 30mm thinwall steel cartridge cases. The steel is to be supplied boron treated to provide the hardenability required to harden and temper the cartridge cases to the desired mechanical properties.

B. Chemistry

The steel grade shall be AISI 10B22. The following chemical composition limits apply. These limits shall be subject to the product analysis limits as specified by ASTM A29.

Chemistry Continued

Element	Ladle Analysis (%)
C	0.18 - 0.23
Mn	0.70 - 1.00
P	0.025 Max.
S	0.020 Max.
Si	0.10 Max.
B	0.0005 - 0.003

C. Austenitic Grain Size

The steel shall be produced by a fine grain practice.

D. Cold Extrusion Quality B

Steel bar purchased in accordance with this specification is to be used for the manufacture of the 30mm thinwall steel cartridge case. These cases are manufactured from slugs by upsetting the slug, backward extruding, and then drawing and ironing the case to final configuration. The steel shall be capable of being cold formed into the cartridge case configuration using Amron's established manufacturing process. Process details are available to the steel supplier at Amron. Heats of steel which produce excessive breakage during the cold forming operations shall be subject to rejection based on negotiations between Amron and the steel supplier.

E. Dimensions and Tolerance

The bar shall be provided as follows:

Diameter: 1.312 plus .012 minus .012 inches
Length: 16 feet plus 1 inch minus 0 inches

Tolerances not specified shall be in accordance with the standard tolerances for hot rolled bar as specified by ASTM A29.

IV. QUALITY ASSURANCE PROVISIONS

The steel supplier shall be responsible for complying with the quality assurance provisions of ASTM A576 and ASTM A29. Quality assurance provisions not specifically established by the ASTM specifications shall be in accordance with the supplier's standard commerical practice.

PREPARATION FOR DELIVERY

A. Packing

Bars shall be provided in secured bundles. Bundle weight shall not exceed 10,000 lbs.

B. Marking

Each bundle must be legibly and indelibly marked as a minimum with the supplier's name, the Amron purchase order number, the weight, and the applicable heat number.

C. Certification

A certification indicating that the steel complies with the requirements of ASTM A576 must be provided for each shipment. The certification must contain the actual ladle analysis of all heats represented in the shipment.

APPENDIX B

COATING STUDY TEST PLAN

STATEMENT OF WORK

COATING STUDY

FOR

30MM L.W. CARTRIDGE CASE

I. Evaluate Coatings:

A. Evaluate the following coatings applied over phosphate substrate per specification TT-C-00490.

1. Northern Varnish LX-1060 (Exterior), Mader Lacquer #358.7.2.0004 (Interior)

2. Mader Lacquer #350.9.70001 (Exterior) and #358.7.2.0004 (Interior)

B. Evaluate the following coating applied over zinc and chromate substrate per specification ASTM B633:

1. Northern Varnish LX-1060 exterior only

2. Midland Dexter exterior only

II. Coating Study Facilities:

A. Amron to provide firing test range and all necessary personnel and test equipment to perform this coating study.

1. 30mm, AAH ADEN Mann Barrel - BGP-1-00019-001

2. 30mm, AAH Breech Block - STD-GA-2 (Modified)

3. Extraction Force Gage - Amron #TR-1-00019-001

B. Test will be performed using fully annealed copper washers to provide spacer between breech block and base of cartridge case.

1. Amron will provide fully annealed copper washers of adequate thickness in .005 inch increments to determine what washer size will produce moderate to heavy stretch (necking) on the exterior of the cartridge case.

2. After copper washer size has been determined, this size will be used for all tests.

III. Prepare Test Cartridge:

A. Amron to provide the following LAP cartridges:

1. Forty (40) cartridges, Mader Lacquer over phosphate substrate.

2. Twenty (20) cartridges, Northern Varnish #LX-1060 over phosphate substrate.

3. Twenty (20) cartridges, Northern Varnish #LX-1060 over zinc plate and chromate base.

4. Twenty (20) cartridges, Midland Dexter Varnish over zinc plate and chromate base.

IV. Evaluation Tests:

A. Pressure Test

1. Record peak pressure in pound per square inch.

B. Washer Crush Test

1. Measure copper washer before and after each test firing to determine set-back.

C. Cartridge Case Extraction Force Test

After cartridge has been fired, measure and record force required to extract spent cartridge case from chamber of Mann barrel using extraction force gage TR-1-00019-001.

D. Develop relative effect numerical value to rate degree of stretch/necking experienced on exterior of cartridge case after each test firing.

V. Firing Tests:

A. Test fire at ambient temperature cartridges coated with Mader Lacquer over phosphate substrate to determine copper washer size that will produce moderate to heavy stretch/necking on the exterior of the cartridge case.

B. Using same washer size, test fire cartridges coated with Northern Varnish #LX-1060 over zinc plate and chromate base.

C. Using same washer size, test fire cartridges coated with Northern Varnish #LX-1060 over phosphate substrate.

D. Using same washer size, test fire cartridges coated with Midland Dexter Varnish over zinc plate and chromate base.

VI. Results:

A. Document and record firing results per evaluation test procedure.

APPENDIX C

TEMPERATURE AND HUMIDITY RETEST REPORT

STEEL CASE FOR 30mm CARTRIDGE, M788 and M789

TEST REPORT

P.O. 63716-RB SUPPLEMENT #01

22 SEPTEMBER 1986

PREPARED FOR: AMRON CORPORATION
525 PROGRESS AVENUE
WAUKESHA, WISCONSIN 53186

BY: V.H. STROBUSH

SENIOR PRINCIPAL DEVELOPMENT ENGINEER

HONEYWELL INC.
DEFENSE SYSTEMS DIVISION
5640 SMETANA DRIVE
MINNETONKA, MINNESOTA 55343

TITLE:	Supplement #01 Test Report
SUBJECT:	LW30 Steel Cased Ammunition P.O. 63716-RB Supplement #01
MATERIAL TESTED:	122 Cartridges Consisting of 102 LW30mm TP Cartridges With a Matrix of Cartridges Cases (3) and Primers (2) Along With 20 20mm TP Cartridges w/out Propellant.
TEST INITIATED:	4 August 1986
TEST COMPLETED:	11 September 1986
TEST CONDUCTED:	Temperature Humidity (TD30) - Attachment 1
RESULTS:	All groups exhibited significant growth in primer resistance. Four (4) of 6 LW30mm groups had units with excessive action times. See attachments for details.

ATTACHMENT 1

Test No: LW30-SC3

Description: Temperature-Humidity per MIL-STD-331A, Test 105.1 (Ref TD-20 Rev E)

Test Item: LW30mm TP Cartridge with Case/Primer Matrix (See Attachment 2)

Quantity: 122

Procedure: Cartridges were placed in the temperature humidity chamber horizontally on 2 chrome plated racks. Groups were alternated (ie. A1,B1,C1...H1,A2,B2...etc) so that they were randomly dispersed within the chamber (see attachment 3). The 28 day (2 cycle) test, as described in test 105.1, was conducted.

All test items were examined visually after 14 days (1 cycle) and after 28 days and any corrosive anomaly noted including photographic documentation. Primer resistance between case and button was measured prior to the T&H test, after the 14 day cycle, after the 28 day cycle and just before ballistic firing. All LW30 cartridges (except 2) were subjected to ballistic test in the M230 mann barrel where in velocity, pressure, action time and mps were measured.

Results: External examination indicated excessive corrosive residue only on the 20mm cases. The LW30 aluminum cases were clean and the LW30 steel cases exhibited only minor residue at the primer and projectile interface. All groups showed significant primer resistance (button to case) increase as the test progressed (see attachment 4). Ballistically the rounds had normal velocity and pressure for post T&H firings, but several had action times in excess of the 4 ms requirement. Resistance was not a true indication of action time however (see attachment 5). Two (2) units from group C and the 20 units from groups G & H were sent to ARDEC for failure analysis.

Conclusion: Groups A & B passed and groups C, D, E & F failed due action times in excess of 4 ms. No failure analysis was conducted.

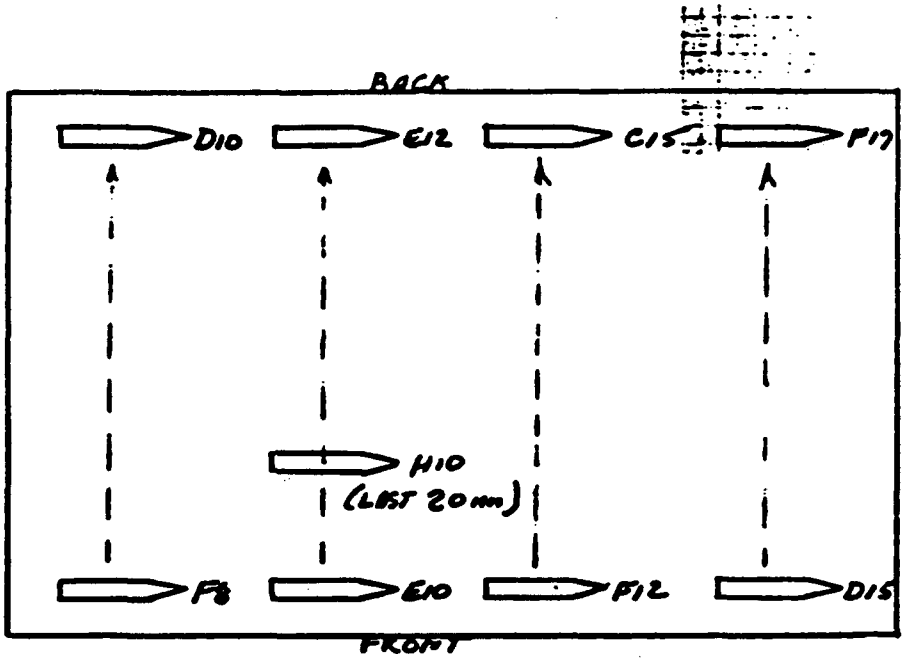
ATTACHMENT 2

TEST MATERIAL CONFIGURATIONS

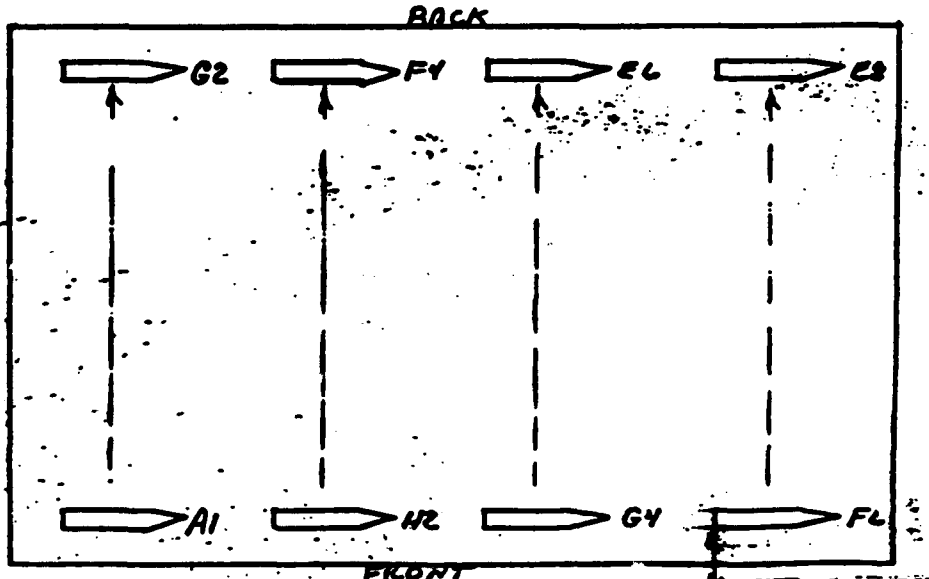
DESIGNATION	DESCRIPTION
A	LW30mm TP Cartridge w/AMRON Aluminum Case and ICI PA520 Primer.
B	LW30mm TP Cartridge w/AMRON Aluminum Case and OLIN PA520 Primer.
C	LW30mm TP Cartridge w/PIPER Aluminum Case and ICI PA520 Primer.
D	LW30mm TP Cartridge w/PIPER Aluminum Case and OLIN PA520 Primer.
E	LW30mm TP Cartridge w/AMRON Steel Case and ICI PA520 Primer.
F	LW30mm TP Cartridge w/AMRON Steel Case and OLIN PA520 Primer.
G	20mm TP Cartridge w/Steel Case, ICI PA520 Primer and w/o Propellant.
H	20mm TP Cartridge w/Steel Case, OLIN PA520 Primer and w/o Propellant.

ATTACHMENT 3

ORIENTATION OF CARTRIDGES IN T&H CHAMBER



TOP CHAMBER RACK



BOTTOM CHAMBER RACK

ATTACHMENT 4.

PRIMER RESISTANCE - LW30mm TEMPERATURE & HUMIDITY TEST MATRIX

PRIMER RESISTANCE - BUTTON to CASE (ohms)

TEST GROUP	AS BUILT	START TEST 7-29-86	AFTER 1 CYCLE 8-21-86	AFTER 2 CYCLES 9-9-86	PRIOR FIRING 9-11-86
A1	30	42	410	2690	2615
2	42	40	440	3060	3700
3	100	191	1210	6530	9020
4	150	122	820	5440	5310
5	39	38	1200	4750	4770
6	130	170	1020	17020	17900
7	75	82	740	6970	6950
8	40	40	330	3300	2900
9	80	80	480	6770	7300
10	55	70	560	6700	6150
11	75	74	550	5500	4800
12	55	59	250	1640	1647
13	45	40	1020	12950	12650
14	55	53	300	4500	4490
15	60	65	420	4420	4610
16	47	49	210	1500	1541
17	90	114	1350	7030	7360
AVERAGE	74	79	671	6002	6115
STD DEV	42	47	344	3876	4115
MINIMUM	30	30	210	1500	1541
MAXIMUM	100	191	1350	17020	17900

PRIMER RESISTANCE - BUTTON to CASE (ohms)

TEST GROUP	AS BUILT	START TEST 7-29-86	AFTER 1 CYCLE 8-21-86	AFTER 2 CYCLES 9-9-86	PRIOR FIRING 9-11-86
B1	28	28	90	250	227
2	45	43	150	370	351
3	26	25	120	320	330
4	32	29	100	640	620
5	34	31	120	300	260
6	55	56	160	340	351
7	27	25	80	190	195
8	37	26	220	440	424
9	35	33	390	3310	3500
10	28	27	90	210	221
11	30	29	140	490	430
12	40	39	82	150	169
13	30	30	100	250	257
14	50	46	140	610	619
15	30	30	60	130	126
16	35	34	120	330	375
17	30	30	120	300	436
AVERAGE	35	33	139	512	529
STD DEV	8	8	76	735	799
MINIMUM	26	25	60	130	126
MAXIMUM	55	56	390	3310	3500

C1	55	70	5230	17240	10400
2	68	82	1510	10170	9000
3	140	151	540	6400	6490
4	85	94	710	6510	8230
5	150	170	82000	OPEN	2000000
6	70	85	34000	OPEN	2900000
7	75	81	3010	16200	13300
8	140	136	95900	OPEN	2300000
9	95	101	390	1130	1109
10	60	69	1210	3430	3570
11	100	105	7550	OPEN	1760000
12	65	75	2630	OPEN	HOLD
13	110	141	4010	OPEN	HOLD
14	70	79	540	6490	6330
15	150	161	1500	8700	8750
16	120	100	2700	45000	48300
17	130	129	790	2510	2470
AVERAGE	99	108	14491	13264	459077
STD DEV	34	33	29346	18200	1137825
MINIMUM	55	69	390	1130	1109
MAXIMUM	150	170	95900	OPEN	2900000

D1	32	33	140	460	485
2	35	34	110	320	316
3	30	30	120	370	379
4	32	32	130	500	470
5	35	35	200	550	562
6	32	32	100	440	512
7	35	33	100	240	256
8	30	29	100	430	464
9	35	34	190	630	582
10	30	36	310	300	307
11	30	29	160	540	535
12	37	37	120	530	339
13	35	35	200	520	546
14	35	35	170	610	626
15	50	49	770	3170	3500
16	50	48	300	1200	1402
17	40	44	310	810	813
AVERAGE	37	37	205	496	712
STD DEV	8	9	158	684	765
MINIMUM	30	29	100	240	256
MAXIMUM	60	64	770	3170	3500

PRIMER RESISTANCE - LW30mm TEMPERATURE & HUMIDITY TEST MATRIX

PRIMER RESISTANCE - BUTTON to CASE (ohms)

TEST GROUP	AS BUILT	START TEST 7-29-86	AFTER 1 CYCLE 8-21-86	AFTER 2 CYCLES 9-9-86	PRIOR FIRING 9-11-86
E1	45	49	510	2470	2422
2	60	59	2070	18750	18480
3	37	38	1700	15400	15100
4	40	43	500	4600	4570
5	60	64	410	2440	2490
6	40	42	5170	174100	163000
7	80	93	1600	6620	6860
8	69	60	470	1050	850
9	50	51	2310	8060	7830
10	40	42	350	1460	1700
11	110	134	490	1240	1167
12	80	100	1250	5810	5770
13	50	49	330	700	585
14	35	40	990	3370	3450
15	130	143	9300	22700	18900
16	80	86	560	1760	1460
17	65	73	2200	15300	15300
AVERAGE	63	70	1834	14344	15414
STD DEV	27	32	2382	41130	38458
MINIMUM	35	38	330	700	585
MAXIMUM	130	143	9300	174100	163000

PRIMER RESISTANCE - BUTTON to CASE (ohms)

TEST GROUP	AS BUILT	START TEST 7-29-86	AFTER 1 CYCLE 8-21-86	AFTER 2 CYCLES 9-9-86	PRIOR FIRING 9-11-86
F1	24	24	340	890	840
2	24	23	330	1320	740
3	20	19	120	340	350
4	34	26	340	890	873
5	26	25	290	3010	1160
6	60	57	710	3500	39300
7	26	24	220	680	637
8	20	20	330	1000	1100
9	20	20	370	1810	2105
10	26	26	310	1100	1340
11	50	50	330	890	905
12	20	19	350	1110	1100
13	22	19	150	690	694
14	24	22	470	1340	1290
15	24	24	250	810	830
16	18	19	340	1010	900
17	20	20	440	1120	1140
AVERAGE	27	26	330	1270	3270
STD DEV	11	11	132	834	9293
MINIMUM	18	19	120	340	350
MAXIMUM	60	57	710	3500	39300

NO PROPELLANT

G1	135	143	940	1830
2	50	53	620	1330
3	45	49	260	350
4	40	46	300	400
5	42	51	520	1250
6	110	116	600	920
7	100	115	420	600
8	120	127	560	960
9	65	70	390	840
10	95	117	500	1270
AVERAGE	82	92	519	1015
STD DEV	34	36	195	413
MINIMUM	42	49	260	400
MAXIMUM	135	143	940	1830

NO PROPELLANT

H1	42	42	300	810
2	45	40	810	4700
3	55	56	470	1340
4	32	33	240	720
5	48	51	1020	3700
6	40	41	200	640
7	30	37	290	730
8	55	55	410	1130
9	50	48	420	3150
10	30	30	270	620
AVERAGE	44	44	466	1780
STD DEV	8	8	271	1519
MINIMUM	32	33	200	640
MAXIMUM	55	56	1020	4700

ATTACHMENT-5

BALLISTIC RESULTS - LW30mm T&H TEST MATRIX

TEST GROUP	PRIMER RESISTANCE (ohms)	MUZZLE VELOCITY (m/s)	CASEMOUTH PRESSURE (psi)	ACTION TIME (ms)	TEST GROUP	PRIMER RESISTANCE (ohms)	MUZZLE VELOCITY (m/s)	CASEMOUTH PRESSURE (psi)	ACTION TIME (ms)
A1	2615	810.7	53500	2.607	B1	227	814.9	50150	2.568
2	3780	815.7	54700	2.526	2	351	816.9	54250	2.648
3	9020	809.4	53950	3.355	3	338	816.8	54850	2.589
4	5310	811.1	53000	2.488	4	420	816.0	54200	2.452
5	4770	814.5	54050	2.511	5	248	815.8	54850	2.517
6	17900	812.3	53750	2.714	6	351	815.1	53350	2.532
7	6950	814.8	55600	2.563	7	195	814.8	53550	2.455
8	2980	813.9	54550	2.465	8	424	817.5	54700	2.589
9	7300	807.4	55000	2.566	9	3500	816.1	54200	2.640
10	6150	817.4	57050	2.651	10	221	815.4	53500	2.491
11	4800	816.6	55350	2.773	11	430	815.8	54150	2.609
12	1647	811.8	53150	2.469	12	169	815.1	53350	2.486
13	12650	815.7	55200	3.003	13	257	819.8	55450	2.540
14	4490	815.7	54550	2.487	14	619	812.1	52300	2.672
15	4610	820.4	56950	2.528	15	126	816.6	54100	2.507
16	1541	812.2	53700	2.651	16	325	817.0	53750	2.646
17	7360	816.9	55650	2.546	17	436	814.1	53750	2.464
AVERAGE	6115	813.9	54600	2.651	AVERAGE	529	815.8	53791	2.545
STD DEV	4115	3.3	1192	0.237	STD DEV	799	1.6	1189	0.074
MINIMUM	1541	807.4	53000	2.465	MINIMUM	126	812.1	50150	2.452
MAXIMUM	17900	820.4	57050	3.355	MAXIMUM	3500	819.8	55450	2.672

C1	10400	813.8	53050	2.511	D1	485	809.2	54250	2.585
2	[illegible]	813.4	53100	2.559	2	316	813.8	53300	2.499
3	[illegible]	[illegible]	52650	2.470	3	379	812.1	52450	2.446
4	8230	811.8	52350	2.614	4	470	813.0	52400	2.526
5	2000000	814.2	52350	96.332	5	542	823.6	57250	6.447
6	2900000	821.6	54900	13.876	6	512	817.6	54900	2.699
7	13300	814.9	52900	2.727	7	254	810.2	52400	2.519
8	2300000	822.0	54650	9.778 160v	8	464	811.8	52350	2.618
9	1189	810.6	55000	2.381	9	582	811.6	52150	2.570
10	3570	811.7	53000	2.592	10	387	812.5	53700	2.520
11	1760000	813.8	52900	10.810 160v	11	535	812.1	52250	2.588
12		NOT TESTED			12	339	811.3	52600	2.442
13		NOT TESTED			13	546	814.6	52850	2.472
14	6330	811.7	52400	2.538	14	626	808.4	51250	2.560
15	8750	812.6	52600	2.488	15	3500	813.9	53550	2.613
16	40300	820.0	54950	2.748	16	1407	825.6	57950	3.873
17	2470	809.8	52650	2.000	17	810	812.9	53650	2.733
AVERAGE	459077	814.8	53537	10.562	AVERAGE	712	813.7	53450	2.819
STD DEV	1137825	3.8	1566	24.807	STD DEV	765	4.6	1788	0.946
MINIMUM	1189	809.8	52050	2.381	MINIMUM	254	808.4	51250	2.446
MAXIMUM	2900000	822	54900	96.332	MAXIMUM	3500	825.6	57950	6.447

BALLISTIC RESULTS - LW30mm T&H TEST MATRIX

TEST GROUP	PRIMER RESISTANCE (ohms)	MUZZLE VELOCITY (m/s)	CASEMOUTH PRESSURE (psi)	ACTION TIME (ms)	TEST GROUP	PRIMER RESISTANCE (ohms)	MUZZLE VELOCITY (m/s)	CASEMOUTH PRESSURE (psi)	ACTION TIME (ms)
E1	2422	812.7	49450	2.867	F1	860	820.6	51100	2.944
2	10400	817.5	49400	5.005	2	740	819.0	52100	3.600
3	15100	814.5	50900	3.759	3	350	809.5	47350	2.605
4	4570	816.5	50850	2.797	4	873	818.4	50300	3.537
5	2490	812.8	48250	2.862	5	1160	821.8	51000	2.860
6	163000	820.0	51000	3.226	6	39300	814.0	49650	7.007
7	6860	822.3	49400	4.062 -	7	637	818.7	50350	3.040
8	850	813.2	49600	2.839	8	1100	818.7	52050	3.191
9	7830	818.6	52250	6.023-	9	2105	817.2	51300	3.499
10	1700	817.8	51250	2.838	10	1340	817.9	50100	3.599
11	1167	814.9	50500	2.589	11	905	812.8	50150	2.809
12	5770	818.3	51300	2.841	12	1100	820.4	52900	3.124
13	585	812.4	49600	2.657	13	694	817.6	51000	2.933
14	3450	805.0	46900	10.760 -	14	1290	816.1	49750	3.241
15	18900	820.3	52150	13.224 -	15	830	811.9	49550	2.801
16	1440	812.6	49650	2.771	16	900	815.7	50200	2.896
17	15300	819.7	52100	3.101	17	1160	815.0	50700	3.140
AVERAGE	15414	815.8	50315	4.413	AVERAGE	3270	816.8	50562	3.343
STD DEV	38450	4.2	1475	3.079	STD DEV	9293	3.3	1244	0.991
MINIMUM	585	805	46900	2.589	MINIMUM	350	809.5	47350	2.605
MAXIMUM	163000	822.3	52250	13.224	MAXIMUM	39300	821.8	52900	7.007

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